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RESULTS OF A SPACE SHUTTLE  
PLUME IMPINGEMENT  
INVESTIGATION  
AT STAGE SEPARATION  
THE NASA-MSFC IMPULSE  
BASE FLOW FACILITY

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## FOREWORD

The research described in this report was conducted by the Lockheed-Huntsville Research & Engineering Center for the Aero-Astrodynamic Laboratory of Marshall Space Flight Center (MSFC), Contract NAS8-26801. The study was performed at the request of Mr. C. Dale Andrews, S&E-AERO-AAE.

The authors are grateful to Mr. Hal Gwin, S&E-AERO-AEG, who was most helpful in his efforts to assure that the required hardware and equipment were available as needed. Thanks are also due Mr. John H. Porter, Northrop Services, Inc., for his supervision of the tests and his critical analysis of the test results in reduced form prior to their receipt by the authors.

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# SUMMARY

Results are presented for an experimental space shuttle stage separation plume impingement program conducted in the NASA-Marshall Space Flight Center's Impulse Base Flow Facility (IBFF). Major objectives of the investigation were to:

1. Determine the degree of dual engine exhaust plume simulation obtained using the equivalent engine;
2. Determine the applicability of the analytical techniques; and
3. Obtain data applicable for use in full-scale studies.

The IBFF tests determined the orbiter rocket motor plume impingement loads, both pressure and heating, on a 3% General Dynamics B-15B booster configuration in a quiescent environment simulating a nominal staging altitude of 73.2 km (240,000 ft). The data included plume surveys of two 3% scale orbiter nozzles, and a 4.242% scaled "equivalent" nozzle — equivalent in the sense that it was designed to have the same nozzle-throat-to-area ratio as the two 3% nozzles and, within the tolerances assigned for machining the hardware, this was accomplished.

The IBFF is a short-duration test facility utilizing scaled versions of hot-flow rocket motors. Combustion chamber temperatures are full-scale values while the operating pressures may or may not match full-scale values. The combustion products and resulting species are equivalent to prototype values.

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# NOMENCLATURE

## Symbols

$A^*$	throat cross-sectional area, $\text{cm}^2$ ( $\text{in.}^2$ )
$A/A^*$	expansion ratio
$D_{\text{equiv}}$	equivalent nozzle exit plane diameter, cm (in.)
$H_2$	hydrogen charge tube or gaseous hydrogen
$H_T$	total pressure probe in hydrogen charge tube
$\dot{m}$	mass flow, gm/sec (lb/sec)
$O_2$	oxygen charge tube or gaseous oxygen
$O_T$	total pressure probe in oxygen charge tube
$P_o, P_c$	combustion chamber pressure, $\text{N/cm}^2$ ( $\text{lb/in.}^2$ )
$P_o^*$	pitot total pressure, $\text{N/cm}^2$ ( $\text{lb/in.}^2$ )
$P_x, P_{\text{imp}}$	local measured pressure on impingement model, $\text{N/cm}^2$ ( $\text{lb/in.}^2$ )
$P_{N_1}$	static pressure tap approximately 0.48 cm from exit plane of nozzle
$\dot{q}$	heating rate, $\text{watts/m}^2$ ( $\text{Btu/ft}^2\text{-sec}$ )
$R$	radial distance, cm (in.)
$r^*$	throat radius, cm (in.)
$X$	axial distance downstream of nozzle exit plane, cm (in.)
$Y$	radial distance from nozzle centerline, cm (in.)
$Z$	radial distance from nozzle centerline, cm (in.)

## Greek

$\alpha$	angle of incidence of orbiter engine centerline relative to top centerline of booster, deg
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Greek

$\theta$  impact probe angle, deg  
 $\psi$  see Fig. 7

Subscripts

j plume jet  
 $\infty$  freestream

## Section 1 INTRODUCTION

The analysis of nozzle flows and the expanding plume has been the subject of many analytical and experimental programs in the past. The state of the art in analytical and empirical plume definition has progressed significantly in the past few years, in particular the capability to predict the impingement effects on a body immersed in the plume flow field (Refs. 1 through 12).

The gasdynamic analysis of the plume and the appropriate scaling parameters for proper plume simulation have been the subject of most of these studies. Reference 12 provides a complete set of usable data for a plume impingement study in the form of nozzle analysis, plume definition and plume impingement on impact probes, a flat plate and quarter-cylinder. Both analytical and experimental results are presented.

The major problems associated with plume impingement in relation to recent space flight tasks have concentrated on the plume expansion and the resultant loads from typical attitude control and auxiliary propulsion systems. With the concepts as envisioned for the space shuttle program the exposed surfaces subjected to impingement loading resulting from stage separation and the ensuing orbiter engine burn create some possible control problems (see, e.g., Refs. 13 and 14).

The capability does not exist (within presently known techniques) to analyze a multiplume flow field such as that which will be found on the space shuttle orbiter vehicle without resorting to extremely cumbersome and time-consuming techniques. The interactions between the individual nozzle plumes cannot be defined analytically, and no empirical techniques are known to exist.

A technique was used, as reported in Ref. 15, to predict impingement loading on a shuttle vehicle by predicting the loads that result from a single nozzle. The method is termed the "effective" or "equivalent" plume analytical technique. This technique can, for more than five nozzle diameters downstream of the exit plane, effectively simulate the corresponding analytical plume periphery shape of a shuttle orbiter engine assembly. Prior to this test there was a lack of experimental data to which results obtained by this technique could be directly compared. This was therefore one of the basic purposes in utilizing both the equivalent nozzle and the dual nozzle assembly. A secondary purpose for using the single equivalent nozzle was to check out the operational characteristics of the hardware.

The purpose of this report is to present the results of an experimental program based on this technique and the comparisons of pressures and heating rates based on the model motor operating conditions.

The plume local flow properties are computed using theoretical flow-field results obtained from the Lockheed Method-of-Characteristics Computer Program (Ref. 16) which have been stored previously on magnetic tape. Real gas equilibrium or frozen thermochemical data are obtained from the computer programs of Refs. 17 and 18, respectively. Effects which can be included in the plume calculations are: (1) treatment of shock waves; (2) fuel striations; (3) nozzle effects; (4) nozzle boundary layer; and (5) plume external flow conditions. The stagnation point heat transfer theory used in calculating the heating rate indicator is that of Fay and Riddell (Ref. 19). Reference 20 contains detailed results of this technique.

## Section 2

### EXPERIMENTAL PROGRAM

#### 2.1 FACILITY DESCRIPTION

The Impulse Base Flow Facility (IBFF) consists of a vacuum tank, vacuum pumping system, nozzle model with supply tubes, gas handling system and required instrumentation. Figure 1 is a schematic of the facility layout. References 21 and 22 present detailed information on the facility and its operating characteristics.

The environmental chamber is a mild steel tank, 5.5 m (18 ft) in diameter and 7.9 m (26 ft) long. The chamber can be evacuated to  $5.0 \times 10^{-4}$  torr for altitude simulations in excess of 91 km (300,000 ft). The chamber is evacuated in three steps:

- Equalize the chamber pressure with a 1189 m<sup>3</sup> (42,000 ft<sup>3</sup>) vacuum sphere to 0.2 N/cm<sup>2</sup> (15mm Hg);
- Evacuate the chamber to  $6 \times 10^{-4}$  N/cm<sup>2</sup> (50 microns Hg) with mechanical pump and blower booster; and
- Further evacuate by diffusion pump to  $0.6 \times 10^{-5}$  N/cm<sup>2</sup> (0.5 micron Hg).

A highly underexpanded plume, with an environmental chamber back pressure of  $0.6 \times 10^{-5}$  N/cm<sup>2</sup> (0.5 micron Hg), results in an effective pressure-altitude simulation during testing of 95 km (310,000 ft).

#### 2.2 TEST TECHNIQUE

Figure 2 is a schematic of a typical hot-flow model and the associated wave process. The charge tubes (hydrogen as the fuel and oxygen as the oxidizer) are prepared at the rated pressure required for the particular test. A

mylar diaphragm restrains the flow of the  $H_2$  and  $O_2$  from the mixing volume of the test model (in this case either the scaled equivalent engine or the scaled orbiter engines). A multiblade cutter ruptures the charge tube diaphragm. Although this is a multilayer, single diaphragm, each charge tube is ruptured simultaneously. The oxidizer/fuel flows into the mixing area of the system. At the same instant, an expansion wave and a shock wave are initiated at the line of the diaphragm rupture. As the process continues, the pressure rises continuously in the mixing area and combustion chamber. At a predesigned pressure level, a mylar diaphragm in the combustion chamber region at the nozzle entrance is ruptured by an overstress on the diaphragm. This second diaphragm ensures that a sharp line exists between the initial flow and choked conditions in the stagnation region of the nozzle. The initial shock proceeds down the nozzle and into the dump (environmental chamber) tank. The initial expansion wave moves simultaneously through the charge tubes in an upstream direction.

The rarefaction waves in the charge tubes proceed at different speeds, since the speed of sound in the hydrogen tube is approximately four times that in the oxygen tube. This fact is accounted for by making the hydrogen charge tube approximately four times the length of the oxygen charge tube.

As the initial shock passes a given point in the flow field (e.g., the exit plane of the nozzle), the useful run time for the test begins. The expansion waves are reflected from the closed end of the charge tubes and move downstream. The passage of the reflected wave past the initiation point (nozzle exit plane) is considered the end of the useful run time. The total process, from diaphragm rupture to the end of the useful run time is approximately 15 to 20 msec, and the useful run time is 6 to 10 msec.

### 2.3 INSTRUMENTATION

For a typical test, all information must be acquired within 10 msec. For these tests, a digital data acquisition system operating at either 40,000,

80,000 or 160,000 samples per second was used. The data acquisition system employed for the first phase has a 32-channel capacity and was operated at the 80,000 samples-per-second rate which gave a single channel speed of five test frames every two milliseconds. A 60-channel FM multiplex data acquisition system with a 40,000 samples-per-second rate was employed for the second phase of testing.

Two types of pressure transducers were used during these tests. High-level pressures were measured with Kistler transducers, a piezoelectric instrument whose charge output is converted to a high-level voltage with a multi-range charge amplifier. Low level pressures were measured with Hidyne transducers, a double-coil, variable reluctance diaphragm instrument used when high sensitivity and fast response are required. Both transducers are calibrated by applying a known pressure and recording the output voltage of the transducer.

Two types of heat sensors were used in this experimental program, both were thin film units (Astro-Space Laboratories, Inc.). The heat sensors located in the leading edge of the vertical tail employed a contoured pyrex substrate that matched the airfoil section used for the tail. The other heat sensors, located on the booster fuselage and on the side of the tail, (at 40% chord) were flat-faced gages. Both sensors utilized a thin (1000 angstroms) strip of platinum flush mounted on a substrate of pyrex. The standard sensors have a nominal room temperature resistance of 100 ohms, a resistance-temperature relationship of approximately 0.18 ohm per degree Celsius, and a sensitivity of 0.0023 ohm per ohm per degree Celsius. The response time of these sensors is 0.1 to 5 microseconds.

The reference pressure of the environmental chamber was monitored with an Alphasat system, and the charge tube pressures were determined using a Bourdon tube system.

## 2.4 MODELS

The test models, described below, include the two 3% scaled orbiter

motors, the scaled 4,242% equivalent motor, impact probe and the aft third of a scaled 3% General Dynamics B-15B Booster. Only the aft portion of the booster was constructed since this is the only part which would experience plume impingement. The model was designed and built by Convair Aerospace so that the remaining fuselage sections could be added if future testing dictated that the complete configuration be used. An additional feature of the model allows a different wing to be attached by rotating the fuselage 180 deg about the model centerline to simulate a high wing configuration. The model fuselage and vertical tail were directly scaled. The wing was a flat plate of the correct planform, but which did not duplicate the airfoil section of the real wing.

The model was constructed of several aluminum sections and attached to a steel sting that matched the support system requirements of the IBFF.

#### 2.4.1 Dual and Equivalent Nozzles

The analytical capabilities within the state of the art of gasdynamic analysis of nozzle flow and plume expansion flow fields do not include the capability of rapidly analyzing the resultant flow field produced by two or more interacting nozzle plumes. The fact that this flowfield analysis requires considerable computer time and is exceedingly cumbersome produces not only the basic question of how the plume properties can be determined, but also the effects of impingement. The plume expansion will intersect in basically the region of keenest interest, the near field region of  $X/D_{\text{exit}} \leq 5$ . Because of the complexity of the flow, the only parameters which can be used to duplicate the flowfield effect are the engine operating parameters, the engine mass flow (total) and the scale size. Although engine operating parameters do not simulate the full-scale vehicle from the standpoint of the "p-l" scaling law (Refs. 2 and 7), they are scaled for mass flows and combustion products. Since the combustion products are not altered by changes in scale size, this leaves the mass flows to be considered for scaling purposes along with geometric scaling.

Thus, to allow analytical assessment of plume properties based on operating conditions of the dual-engine assembly, the equivalent mass flow of the

dual-engine assembly must be the controlling parameter for scaling the "equivalent" nozzle. (See Fig. 3 for a schematic of the equivalent nozzle and Table 1 for the equivalent nozzle contours.) The geometry of the equivalent engine is the same as that used in the 3% model, with the scale factor based on identical mass flows resulting in a scale size of 4.242% for the single equivalent engine.

The equivalent nozzle was used for all baseline measurements and analytical analyses for plume predictions, as well as to assess operational characteristics of the overall system. These conditions were used to compare booster model impingement data with the dual-engine assembly in both vertical and horizontal orientations.

The true scaled nozzle and combustion chamber pressure would require, for actual viscous terms simulation, a pressure of  $7 \times 10^4 \text{ N/cm}^2$  (100,000 lb/in.<sup>2</sup>), which is not feasible to consider. Therefore, a nominal combustion chamber pressure of  $689 \text{ N/cm}^2$  (1000 lb/in.<sup>2</sup>) was chosen for convenience. Since the full-scale vehicle requires a combustion chamber pressure of three times this value,  $2100 \text{ N/cm}^2$  (3000 lb/in.<sup>2</sup>), the pressure ratio across the jet at the exit plane referenced to freestream pressure ( $P_j/P_\infty$ ) is a factor of three too low to simulate the  $P_j/P_\infty$  at 73 km (240,000 ft) for the full-scale vehicle. In order to maintain the nominal pressure ratio, the environmental dump tank was maintained at a pressure corresponding to a slightly higher altitude. This pressure difference made the proper adjustment for simulating the pressure ratio required to allow the full plume expansion found at 73 km (240,000 ft) operating at a combustion chamber pressure of  $2100 \text{ N/cm}^2$  (3000 lb/in.<sup>2</sup>).

See Reference 23 for a complete description of the analytical techniques employed for this test program and an assessment of the analytical/experimental data.

The operating conditions and geometry of the dual and equivalent engine systems are shown in the table on the following page.

Parameter	Engine	
	Dual	Equivalent
$P_o$ , N/cm <sup>2</sup> (lb/in. <sup>2</sup> )	689.5 (1000)	689.5 (1000)
$\dot{m}$ , gm/sec (lb/sec)	269.4 (0.592)	269.4 (0.592)
$r^*$ , cm (in.)	0.3632 (0.1430)	0.5194 (0.2045)
$A^*$ , cm <sup>2</sup> (in. <sup>2</sup> )	0.4144 (0.0642)	0.8475 (0.1314)
$A/A^*$	170	167
Scale, %	3	4.242

The two simulated orbiter motors (Fig. 4) utilized in these tests were 3% scale models designed by Lockheed-Huntsville Research & Engineering Center and fabricated in the NASA-MSFC shops. The baseline nozzle contour of Aerojet General's 400,000 lbs thrust engine (Ref. 24) was simulated as closely as possible (Table 2) without resorting to the extremes which would be required for scaling the surface roughness. The necessary degree of scaling the surface roughness of the models to that of the actual hardware is at present an unknown quantity (Ref. 2)\*. The upstream portions of the motors, shown schematically in Fig. 5 were also not scaled. The mixing and combustion chambers were not simulated, nor were the injection systems for the fuel/oxidizer combination. The stagnation chamber pressures were different from both the full scale values and simulation requirements presented in Ref. 2 as necessary to account for nozzle Reynolds number, but the oxidizer-to-fuel ratio was correlated with that of full scale, using gaseous oxygen and hydrogen constituents for simulation purposes. This resulted in the proper combustion products and species breakdown.

#### 2.4.2 Engine Hardware

The capability was designed into the nozzle hardware to accomplish:

\*Assignment of a  $\pm 0.005$ -inch tolerance for machining purposes precluded the possibility of exactly matching the prototype contour and maintaining the same nozzle-throat-to-exit-area ratio between the two 3% engines and the equivalent engine.

- vertical engine orientation for low crossrange simulation;
- horizontal engine orientation for high crossrange simulation; and
- stored orbiter engine contour for an abort simulation.

The abort configuration is simply a shorter nozzle for this testing purpose having an area ratio,  $A/A^*$ , of 91:1. The technique for these tests was to have a separation line, as shown in Fig. 4, in order that the downstream end of the nozzle can be removed from the nozzle assembly.

The vertical and horizontal orientations are achieved by allowing the assembly plate on which the nozzles are mounted to be rotated 90 degrees.

The dual engine or equivalent engine configuration is installed by utilizing the appropriate port housing. See Fig. 5 for details.

#### 2.4.3 Impact Probes

The plume flowfield impact pressures (pitot total) were measured with probes having the configurations shown in Fig. 6. The impact probe denoted as being Probe A was used for all near-field measurements. Probe B was used for intermediate measurements and all far-field measurements. Included in Fig. 7 is a schematic of the impact probe/orbiter nozzle axis system. The impact probe and mounting mechanism allowed the impact probe to be aligned with the flow along a given direction, which was predicted as being the angle realized by the streamlines at that locale. Figures 8, 9, and 10 are photographs of the impact probes and the equivalent nozzle, the two 3% horizontal arrangement and the two 3% vertical arrangement. Figures 11 through 34 are plots of the plume data.

#### 2.4.4 Stagnation Point Heating Rate Probes

The stagnation point heat transfer rates for the exhaust plumes were measured with probes having the configuration shown schematically in Fig. 6

and pictorially in Fig. 8. The stagnation heating rate probes consisted of a 2.06 cm (0.81 in) diameter hemisphere-cylinder with a 0.318 cm (0.125 in) diameter flat-faced thin film heat transfer gauge located at the stagnation point.

#### 2.4.5 Booster

The booster model employed for these tests, a 3% version of the General Dynamics low delta wing/vertical tail vehicle, is shown schematically in Figs. 35, 36 and 37 with photographs of the actual model and support system shown in Figs. 38, 39 and 40. The schematics shown in Figs. 35 and 36 indicate 100 instrumentation ports with 60 allocated for pressure and 40 for thin film heat transfer measurements.

### 2.5 MOTOR/BOOSTER RELATIVE TEST POSITIONS

The test positions for the plume impingement tests on the General Dynamics model are shown in Fig. 41. The dimensions listed in Fig. 41 are all relative to the exit plane of the nozzle assembly being used, whether it is the single or dual nozzle assembly.

Since the nozzle assembly was fixed, angle of incidence was obtained by moving the booster reference point centerline with respect to the orbiter engine exit plane centerline.

Figure 42 depicts the model geometry and engine arrangement for this test.

### 2.6 DATA TABULATION

Tables 3 and 4 are typical examples of the run log and reduced data output for the plume surveys and plume impingement tests. Because of the bulk

of data accumulated during these tests, the run logs are not included in this report. Table 5 is an index of the plume impact pressure surveys with the tabulated results included in Tables 6 through 82. Table 83 is an index of the plume impact heating rate surveys with the tabulated results included in Tables 84 through 112. Table 113 is an index of the booster impingement test conditions with the tabulated results included in Tables 114 through 179. A complete set of the run logs is available through NASA-MSFC release authorization.

The data as shown in Table 4, which is a direct copy of the original printout, are reduced with a computer program written by NASA-MSFC for compatibility with the IBFF data acquisition system.

## 2.7 DATA ACCURACY AND REPEATABILITY

In general, as is the case with any test facility when the test instrumentation is pushed well beyond the design limits, the accuracies and repeatabilities fall below a desired level, but the data must still be used since it is a state-of-the-art matter. Development work in the area of extremely low pressure measuring devices is an ongoing project to advance the capabilities of this facility. Results to date are extremely encouraging. In the ranges for which the present system was designed, the day-to-day accuracies and repeatabilities were within a level of  $\pm 25\%$  of full scale. There are points which may be found to be outside this range, but the trends on any given test are well-defined values. The accuracy in absolute numbers represents a variable quantity. The higher pressure levels are the most accurate, with an absolute level of  $\pm 10\%$ . At the extreme farfield and radial locations tested, accuracies of  $\pm 50\%$  represent the acceptable limits for pressure measurements since the transducers are being operated in an environment beyond their design capability. The heat transfer measurements are considered to have closer tolerances since, where the heating rates are predicted to be outside a given upper or lower limit (depending on several variables), no attempt was made to measure the values. The heat transfer results, then, are considered to be within  $\pm 20\%$ .

Data points found to be outside the trend of values, particularly on plume centerline measurements, can in all probability be attributed to impingement of mylar diaphragm particles on the heat sensors and into the pressure transducers.

## 2.8 ALIGNMENT ACCURACIES

Test hardware was aligned by optical and mechanical means relative to the exit plane of the nozzle being tested. The location tolerances for the impact probes and the booster model for the staging impingement tests were as follows:

### Impact Probe

$$X = \pm 0.125 \text{ cm } (\pm 0.050 \text{ in.})$$

$$Y = \pm 0.125 \text{ cm } (\pm 0.050 \text{ in.})$$

$$Z = \pm 0.125 \text{ cm } (\pm 0.050 \text{ in.})$$

$$\psi = \pm 0^\circ 10 \text{ min}$$

### Booster Model

$$X = \pm 0.125 \text{ cm } (\pm 0.050 \text{ in.})$$

$$Y = \pm 0.125 \text{ cm } (\pm 0.050 \text{ in.})$$

$$Z = \pm 0.125 \text{ cm } (\pm 0.050 \text{ in.})$$

$$\alpha = \pm 0^\circ 10 \text{ min}$$

### Section 3 EXPERIMENTAL RESULTS

The results of this experimental program were obtained in two phases. A new model support system was installed between the end of Phase I and the beginning of Phase II. Installation of the system required a thirty-day shut-down of the IBFF during which time a 60-channel data acquisition system was also installed. The divisions of each phase are listed below.

#### Phase I

- Test 019: Plume Surveys at  $X/D = 4, 12$  and  $15$
- Test 020: Model Impingement Tests

#### Phase II

- Test 021: Plume Surveys at  $X/D = 2, 4, 10$  and  $15$
- Test 022: Model Impingement Tests
- Test 024: Plume Surveys at  $X/D = 1$  and  $2$

All plume heating data presented in Figs. 29 through 34 has been normalized to a chamber pressure of  $386.1 \text{ N/cm}^2$  ( $560 \text{ lb/in}^2$ ). The booster impingement pressure data are presented in Figs. 43 through 90 and the booster impingement heating data are presented in Figs. 91 through 118. The booster heating data were normalized to a chamber pressure of  $689.5 \text{ N/cm}^2$  ( $1000 \text{ lb/in}^2$ ). The actual experimental values are listed in the applicable data sheets.

The normalizing equation in both cases was

$$\dot{q}_{\text{normalized}} P_c = \dot{q}_{\text{measured}} \sqrt{\frac{P_{c \text{ normalized}}}{P_{c \text{ measured}}}}$$

### 3.1 PLUME IMPACT PRESSURE SURVEYS

Analytical predictions of the properties of the plume flow field were compared and analyzed with these experimental results and published in Ref. 23.

The surveys of the plume flow field are listed in Table 5 and the results are listed in Tables 6 through 82. Plots of the plume survey data are shown in Figs. 11 through 28.

### 3.2 BOOSTER IMPINGEMENT DATA

Analytical predictions and analysis of the orbiter plume impingement on the booster were compared and analyzed with the experimental results and published in Ref. 23.

The test conditions and engine configurations to which the booster model was subjected are listed in Table 113, and the results are listed in Tables 114 through 179. Plots of the booster impingement data are shown in Figs. 43 through 90.

Full scale axial force, normal force and pitching moment data which were derived from Phase I of the test data are presented in Ref. 25.

### 3.3 DATA ANALYSIS/REDUCTION

The complete time history trace of run 63/0 reveals the typical data curves generated by plotting selected output from the digital data acquisition system (Fig. 119). The  $O_2$  and  $H_2$  charge tubes are charged to their pretest pressure of approximately 1300 psia and their output is nulled to zero. Because of the method used in calibration, a negatively increasing value of counts output represents a decreasing pressure from the 1300 psia starting point. In the case of Fig. 119, which is a reproduction of run 63/0, or the dual-vertical engine, the net output at the average value for what was considered

the test frames, was -930, and -953 counts for the charge tubes. With a sensitivity of 1.4245 and 1.4163 psi/count, respectively, these represent a net pressure reading of 1357 and 1317 psia.

The diaphragm rupture occurs in this case at approximately the 51st frame with almost instantaneous response by the instrumentation. Analysis of these curves generally begins with an inspection of the chamber pressure curve to see if it exhibits a rapid rise time to a steady state chamber pressure. Coupled with this observation is an inspection of the  $O_2$  and  $H_2$  curves to see if they indicate a characteristic drop in pressure followed by a subsequent leveling off and if the slopes of the two curves are somewhat "parallel" to each other. The assumption made during the  $O_2$  and  $H_2$  curve inspection is that if the two curves are relatively flat and parallel then this time frame represents one of a constant O/F ratio. Another measurement examined to determine the lower limit of test frame data is the  $P_{N_1}$  static pressure curve. Generally this curve corresponds to the chamber pressure curve with a possible difference occurring in the test frame number associated with the onset of instrumentation response.

To determine the upper limit of test frame data associated with a previously selected test frame range in the flat portion of the chamber pressure curve requires considerable experience and "feel" for the data curves obtained from the IBFF. For this reason a more general discussion of the remaining data analysis will be attempted. To determine the upper test frame limit on test data the pressure and temperature curves are examined individually to detect the occurrence of reflected shock effects on the test data. Remembering that the IBFF is a cylindrical tank 5.5m (18 ft) in diameter with a scaled rocket engine firing for approximately 30 milliseconds, the existence of shock waves reflected off the inside walls is a certainty. Depending upon the location of the instrumentation, axially and radially with respect to the centerline of the engines, it may be subject to reflected shocks. The influence, if any, on the data curves will be readily apparent and the test frame associated with this disturbance will represent the upper limit of test

data for that specific measurement. The test frames selected for examination and determination of the time-averaged value for that measurement will generally be in the first level portion, above the tare reading, of that curve. This level portion may correspond to the same test frame numbers selected for determination of the average chamber pressure but generally will be higher test frame numbers. This is possible due to the axial range of instrumentation and the corresponding response lag between a near and far field measurement. The number of test frames selected for determining the time-averaged value of the measurement depends upon the number of frames that correspond to a "level" curve and/or whether the cutoff limitation due to reflected shocks was encountered. The test frames selected as representative of the measurement for each pressure were time averaged using a data reduction program developed by NASA-MSFC and compatible with the IBFF measurements. The test frames selected for the temperature measurements were determined in a similar fashion and coupled with a computer program (Ref. 26) to determine the heating rates.

#### Section 4 CONCLUSIONS

The reported experimental test results represent, primarily, two major considerations or accomplishments. First, a demonstrated capability for short duration testing of space shuttle vehicles during separation in the Impulse Base Flow Facility has been shown, and secondly these results are representative of the type of complete studies needed to verify the analytical predictions of nozzle plume flow fields.

Some points to be considered in designing engine hardware and planning plume impingement tests are as follows. The smallest tolerances possible should be assigned for engine hardware to limit nozzle contour variations from prototype values. After the nozzle has been fabricated, the exact internal contours should be determined by, for example, pouring an RTV mold and determining the nozzle contours from an optical comparator. Data thus obtained can be used as input to the specific theoretical model employed to predict the resulting model nozzle flow field.

If mylar rupture diaphragms are employed for short duration testing, an effort should be made to ascertain if the flow field is relatively free of diaphragm particles. The introduction of any contaminants from rupture diaphragms composed of mylar or cellophane or from ignition sources will appreciably reduce the life span of thin film heat transfer gages and can result in erroneously high heat transfer measurements.

Centerline probe measurements of the plume flowfield(s) were occasionally susceptible to severe particle impingement, in some cases mylar particles were found lodged in the pressure transducers. In several cases the thin film contoured heat sensors suffered erosive pitting of the pyrex substrate and platinum sensing strip.

Occasionally the heat sensors in the rake surveys and the contoured heat sensors experienced a change in resistance (heating rate) greater than 1000 ohms from predictions. In these cases the predicted resistance change was generally an order of magnitude less than the sensor was capable of withstanding. When these sensors were examined, a completely eroded platinum strip and severely pitted pyrex substrate were found. Conversations with Cornell Aeronautical Laboratories, Inc., (Ref. 27) indicate that this is not an unusual occurrence and replacement of the thin film gages with calorimeter type gages eliminated their erosion problem.

During the latter portion of Phase II plume surveys, the IBFF personnel were able to ignite the propellants by an adiabatic compression process that elevated the propellant mixture to the ignition temperature without the use of an igniter. Since only pressure measurements were being monitored during this sequence it is too early to assess the effect of removing a potential contamination source, namely, the igniter.

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Table 1  
EQUIVALENT ORBITER NOZZLE CONTOUR (4.242% Scale)\*

X (cm)	R (cm)	X (cm)	R (cm)	X (cm)	R (cm)
0.0	0.5194	3.0683	2.3063	10.6883	4.8959
0.2108	0.5867	3.3858	2.4727	11.9583	5.1829
0.5283	0.7684	3.7033	2.6226	13.2283	5.4356
0.7391	0.8941	4.3383	2.9032	14.4983	5.6668
0.7391	0.9195	4.9733	3.1585	15.7684	5.8839
0.8458	0.9804	5.6083	3.4036	17.0384	6.0820
1.1633	1.1811	6.2433	3.6297	18.3084	6.2522
1.4808	1.3805	6.8783	3.8430	19.5784	6.4097
1.7983	1.5799	7.5133	4.0450	20.8484	6.5532
2.1158	1.7780	8.1483	4.2355	22.1184	6.7120
2.4333	1.9583	8.7833	4.4158		
2.7508	2.1323	9.4183	4.5834		

\*NOTE: These contour dimensions were obtained from an RTV mold of the actual nozzle.

Table 2  
ORBITER BASELINE NOZZLE CONTOUR (3% SCALE)\*

X (cm)	R (cm)	X (cm)	R (cm)	X (cm)	R (cm)
0.0	0.3632	2.6162	1.8326	9.2837	3.8138
0.0762	0.3670	2.9337	1.9710	9.9187	3.9319
0.1829	0.4026	3.5687	2.2289	10.5537	4.0437
0.3937	0.5347	4.2000	2.4727	11.1887	4.1491
0.6858	0.7366	4.8387	2.6924	11.8237	4.2494
0.7112	0.7506	5.4737	2.8943	12.4587	4.3498
1.0287	0.9627	6.1087	3.0747	13.0937	4.4501
1.3462	1.1582	6.7437	3.2436	13.7287	4.5491
1.6637	1.3462	7.3787	3.4061	14.3637	4.6419
1.9812	1.5265	8.0137	3.5560	14.9987	4.6990
2.2987	1.6878	8.6487	3.6906	15.6337	4.7371

\* NOTE: These contour dimensions were obtained from an RTV mold of the actual nozzle.

Table 3  
TYPICAL RUN LOG -IBFF CALIBRATION DATA

Channel Number	Transducer Location	Zero (counts)	Input Pressure (psia)	Full-Scale Output (counts)
1	-	-	-	-
2	O <sub>2</sub>	4	850	- 721
3	P <sub>C</sub>	- 6	450	738
4	H <sub>2</sub>	4	850	- 715
5	O <sub>T</sub>	- 8	105	- 745
6	H <sub>T</sub>	- 4	105	- 749
7	P <sub>N<sub>1</sub></sub>	- 2	4	711
8	P1	10	0.5	714
9	P2	- 1	0.5	706
10	P3	- 6	0.5	687
11	P4	4	0.5	716
12	P5	0	0.5	696
13	P6	- 1	0.5	709
14	P7	14	0.5	720
15	P8	12	0.5	722
16	-	-	-	-
17	-	-	-	-
18	P9	- 13	0.2	692
19	P10	3	0.2	696
20	P11	- 3	0.2	695
21	P12	7	0.2	710
22	P13	- 10	0.2	680
23	P14	- 4	0.2	689
24	P15	- 2	0.2	664
25	-	-	-	-
26	P16	125	0.2	-
27	P17	0	0.2	699
28	Q1	-	-	-
29	-	-	-	-
30	Q2	-	-	-
31	Q3	-	-	-
32	-	-	-	-

Table 4  
TYPICAL PROGRAM OUTPUT LISTING

YES?	RUN	REFUN	RATE	R0000	SAMPLER PER SECOND	ENGINEERING UNITS, TARE REMOVED					
						COUNTS	TARE	AVERAGE	MAXIMUM	MINIMUM	STD. DEV. RATIO
CHANNEL	AVERAGE	MAXIMUM	MINIMUM	SID. DEV.	TARE	MAXIMUM	MINIMUM	STD. DEV. RATIO	MAXIMUM	MINIMUM	STD. DEV. RATIO
1	-1	-1	-1	000	-1	0.0313	0.0000	0.0000	0.0000	0.0000	0.0000000
2	-670	-566	-692	7	5	497.4257	512.7784	482.2536	512.7784	482.2536	0.0000000
3	820	924	815	3	-1	496.1663	496.5379	493.1017	496.1663	493.1017	0.0000000
4	-680	-673	-703	3	6	479.7137	497.3557	461.8897	479.7137	461.8897	0.0000000
5	-720	-722	-732	3	-7	1107.2011	1198.0509	1106.6422	1107.2011	1106.6422	0.0000000
6	-770	-373	-380	2	3	1246.8121	1247.0397	1246.0331	1246.8121	1246.0331	0.0000000
7	54	562	528	11	19	2.9455	3.0459	2.8561	2.9455	2.8561	0.0000000
8	96	988	911	257	-66	0.1154	0.7465	0.0548	0.1154	0.0548	0.0000000
9	880	919	829	26	-78	0.6771	0.7047	0.6104	0.6771	0.6104	0.0000000
10	660	696	634	16	-66	0.5301	0.5500	0.5059	0.5301	0.5059	0.0000000
11	561	578	542	10	-37	0.4200	0.4316	0.4064	0.4200	0.4064	0.0000000
12	272	279	264	4	-30	0.2169	0.2216	0.2108	0.2169	0.2108	0.0000000
13	347	367	334	6	-49	0.3067	0.3137	0.2975	0.3067	0.2975	0.0000000
14	350	367	333	9	-56	0.2074	0.2998	0.2757	0.2074	0.2757	0.0000000
15	63	69	59	3	91	0.0193	0.0154	0.0224	0.0193	0.0224	0.0000000
16	2	2	2	000	2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000000
17	3	3	3	000	3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000000
18	567	562	553	9	-122	0.1358	0.2000	0.1918	0.1358	0.1918	0.0000000
19	559	568	547	6	-46	0.1750	0.1776	0.1715	0.1750	0.1715	0.0000000
20	530	542	517	7	28	0.1236	0.1470	0.1398	0.1236	0.1398	0.0000000
21	416	424	406	5	-35	0.1201	0.1302	0.1251	0.1201	0.1251	0.0000000
22	237	246	220	9	-218	0.1303	0.1345	0.1270	0.1303	0.1270	0.0000000
23	203	302	296	4	-81	0.1081	0.1106	0.1060	0.1081	0.1060	0.0000000
24	640	661	610	14	39	0.1804	0.1867	0.1714	0.1804	0.1714	0.0000000
25	14	19	10	3	14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000000
26	127	130	122	3	125	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000000
27	191	198	186	3	-74	0.0758	0.0777	0.0743	0.0758	0.0743	0.0000000
28	177	200	152	15	-4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000000
29	-767	-767	-767	000	23	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000000
30	44	72	2	10	39	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000000
31	46	52	30	5	2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000000
32	27	28	27	0	27	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000000

MSFC -- 1UFF

Table 5  
PLUME IMPACT PRESSURE SURVEYS

Table No.	X/D	Engine Config.	Run No.	Symbol	P <sub>c</sub> (psia)	P <sub>∞</sub> (μHg)
6	1.0	1	64/2	□	577.9	4.0
7	1.0	1	65/0	□	695.8	5.0
8	1.0	1	66/0	□	630.5	5.0
9	1.0	1	67/0	□	662.7	2.6
10	1.0	2V	72/2	◇	620.2	4.0
11	1.0	2V	73/3	◇	658.2	4.8
12	1.0	2V	74/0	◇	606.5	4.4
13	1.0	2V	75/0	◇	658.1	2.8
14	1.0	2H	68/1	○	624.0	3.0
15	1.0	2H	69/0	○	627.6	5.0
16	1.0	2H	71/0	○	623.1	4.0
17	1.0	2H	70/0	○	612.8	4.0
18	2.0	1	1/0	□	835.4	5.0
19	2.0	1	2/0	□	549.5	4.0
20	2.0	1	3/0	□	667.6	5.7
21	2.0	1	3/1	□	543.4	5.2
22	2.0	1	76/0	■	671.3	4.0
23	2.0	1	77/0	■	636.0	5.0
24	2.0	2V	34/0	◇	528.9	5.3
25	2.0	2V	35/1	◇	569.2	5.5
26	2.0	2V	36/0	◇	618.9	5.0
27	2.0	2V	78/0	◆	634.8	3.6
28	2.0	2V	79/0	◆	590.9	4.0
29	2.0	2H	37/0	○	614.9	5.0

Table 5 (Continued)

## PLUME IMPACT PRESSURE SURVEYS

Table No.	X/D	Engine Config.	Run No.	Symbol	P <sub>c</sub> (psia)	P <sub>g</sub> (μHg)
30	2.0	2H	38/0	○	605.2	5.5
31	2.0	2H	39/1	○	634.2	5.5
32	2.0	2H	80/1	●	839.8	2.2
33	2.0	2H	81/0	●	601.7	5.0
34	4.0	1	4/0	□	704.7	3.0
35	4.0	1	5/0	□	541.6	4.0
36	4.0	1	6/0	□	592.7	2.5
37	4.0	1	6/0*	□	504.0	3.0
38	4.0	1	47/1*	□	530.3	1.0
39	4.0	2V	5/0*	◊	557.8	5.0
40	4.0	2V	31/0*	◊	637.9	5.2
41	4.0	2V	32/0*	◊	579.1	5.5
42	4.0	2V	33/0*	◊	5	3.0
43	4.0	2V	49/0*	◊	639.1	1.0
44	4.0	2H	48/0*	●	655.3	1.0
45	4.0	2H	40/0*	○	662.7	5.5
46	4.0	2H	41/0*	○	560.9	6.0
47	4.0	2H	42/0*	○	590.5	5.5
48	4.0	2H	4/0*	●	596.1	3.0
49	10.0	1	7/0	□	595.3	3.0
50	10.0	1	8/0	□	596.8	3.0
51	10.0	1	9/1	■	536.7	3.0
52	10.0	1	10/0	□	598.6	3.0

\*Phase I

Table 5 (Continued)  
PLUME IMPACT PRESSURE SURVEYS

Table No.	X/D	Engine Config.	Run No.	Symbol	P <sub>c</sub> (psia)	P <sub>o</sub> (μHg)
53	10.0	2V	27/0	◆	708.5	2.0
54	10.0	2V	28/0	◇	682.9	5.0
55	10.0	2V	29/0	◆	731.7	2.0
56	10.0	2V	30/0	◇	669.6	3.0
57	10.0	2H	43/0	○	618.7	5.0
58	10.0	2H	44/0	◐	675.4	3.2
59	10.0	2H	45/0	◑	626.7	5.5
60	10.0	2H	46/0	◒	682.1	5.0
61	12.0	1	58/0*	□	577.2	2.0
62	12.0	2V	62/0*	◆	656.5	7.0
63	12.0	2V	63/0*	◇	658.4	4.5
64	12.0	2H	60/0*	○	620.6	2.0
65	15.0	1	1/5*	□	608.6	6.5
66	15.0	1	1/6*	◐	542.0	6.0
67	15.0	1	50/0*	◑	527.3	1.0
68	15.0	1	15/0	◒	607.6	5.0
69	15.0	1	16/0	◓	604.3	3.0
70	15.0	1	17/0	◔	604.1	10.0
71	15.0	1	18/0	◕	638.0	3.0
72	15.0	2V	2/0*	◆	534.4	5.5
73	15.0	2V	55/0*	◇	697.4	1.0
74	15.0	2V	57/0*	◆	661.3	2.0
75	15.0	2H	51/0	○	757.5	5.0

\* Phase I

Table 5 (Concluded)  
PLUME IMPACT PRESSURE SURVEYS

Table No.	X/D	Engine Config.	Run No.	Symbol	P <sub>c</sub> (psia)	P <sub>z</sub> (μHg)
76	15.0	2H	52/0	○	725.0	3.0
77	15.0	2H	53/0	○	725.9	2.0
78	15.0	2H	54/0	○	737.9	3.0
79	15.0	2H	51/0*	●	434.8	2.1

\*Phase I

Table 6

IBFR 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_0/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 5.298 in.	0	0	0	0	$1.004 \times 10^{-2}$	—
D = 5.298 in.	2.12	.400	2	36	$6.577 \times 10^{-3}$	—
X/D = 1	3.15	.600	9	30	$2.222 \times 10^{-3}$	—
O/F = 6.0:1	4.24	.800	20	54	$6.681 \times 10^{-4}$	—
$P_{\text{ambient}} = 4.0$ Microns	5.04	.950	28	0	$2.832 \times 10^{-4}$	—
$P_{\text{combustion}} = 577.9$ psia	5.84	1.100	35	0	$8.932 \times 10^{-5}$	—
Engine Type: Equivalent	6.26	1.200	36	24	$1.003 \times 10^{-4}$	—
	7.125	1.350	37	37	$6.185 \times 10^{-4}$	—

Table 7

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		$P_o/P_c$	q (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 5.298 in.	0	0	0	0	$1.138 \times 10^{-2}$	—
D = 5.298 in.	2.12	.400	2	36	$1.237 \times 10^{-3}$	—
X/D = 1	3.15	.600	9	30	Out	—
O/F = 6.0:1	4.24	.800	20	54	$5.685 \times 10^{-4}$	—
P <sub>ambient</sub> = 5.0 Microns	5.04	.950	28	0	$2.616 \times 10^{-4}$	—
P <sub>combustion</sub> = 695.8 psia	5.84	1.100	35	0	$1.117 \times 10^{-4}$	—
Engine Type: Equivalent	6.26	1.200	36	24	$6.295 \times 10^{-5}$	—
	7.125	1.350	37	37	$1.126 \times 10^{-6}$	—

Table 8

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		$P'_0/P_c$	q (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 5.298 in.	0	0	0	0	$9.897 \times 10^{-3}$	—
D = 5.298 in.	2.12	.400	2	36	$7.089 \times 10^{-3}$	—
X/D = 1	3.15	.600	9	30	$2.114 \times 10^{-3}$	—
O/F = 6.0:1	4.24	.800	20	54	$7.199 \times 10^{-4}$	—
P <sub>ambient</sub> = 5.0 Microns	5.04	.950	28	0	$2.719 \times 10^{-4}$	—
P <sub>combustion</sub> = 630.5 psia	5.84	1.100	35	0	$1.263 \times 10^{-4}$	—
Engine Type: Equivalent	6.26	1.200	36	24	$1.833 \times 10^{-4}$	—
	7.125	1.350	37	37	$6.114 \times 10^{-6}$	—

Table 9

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P'_0/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 5.298 in.	0	0	0	0	$1.224 \times 10^{-2}$	—
D = 5.298 in.	2.12	.400	2	36	$6.287 \times 10^{-3}$	—
X/D = 1	3.15	.600	9	30	$1.992 \times 10^{-3}$	—
O/F = 6.0:1	4.24	.800	20	54	$5.695 \times 10^{-4}$	—
P <sub>ambient</sub> = 2.6 Microns	5.04	.950	28	0	$2.695 \times 10^{-4}$	—
P <sub>combustion</sub> = 662.7 psia	5.84	1.100	35	0	$1.168 \times 10^{-4}$	—
Engine Type: Equivalent	6.25	1.200	36	24	$3.231 \times 10^{-4}$	—
	7.125	1.350	37	37	$2.829 \times 10^{-5}$	—

Table 10

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		$P_o/P_c$	$q$ (Btu/l <sup>2</sup> -sec)
			(deg)	(min.)		
X = 5.298 in.	0	0	0	0	$4.997 \times 10^{-3}$	—
D = 5.298 in.	2.12	.400	2	36	$1.074 \times 10^{-2}$	—
X/D = 1	3.15	.600	9	30	$6.884 \times 10^{-3}$	—
O/F = 6.0:1	4.24	.800	20	54	$3.361 \times 10^{-3}$	—
P <sub>ambient</sub> = 4.0 Microns	5.04	.950	28	0	$1.152 \times 10^{-3}$	—
P <sub>combustion</sub> = 620.2 psia	5.84	1.100	35	0	$5.935 \times 10^{-4}$	—
Engine Type: 2V-3%	6.26	1.200	36	24	$3.053 \times 10^{-4}$	—
	7.125	1.350	37	37	$1.052 \times 10^{-4}$	—

Table 11

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		$P'_0/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 5.298 in.	0	0	0	0	$3.409 \times 10^{-3}$	—
D = 5.298 in.	2.12	.400	2	36	$9.888 \times 10^{-3}$	—
X/D = 1.0	3.15	.600	9	30	$7.129 \times 10^{-3}$	—
O/F = 6.0:1	4.24	.800	20	54	$3.222 \times 10^{-3}$	—
$P_{ambient} = 4.8$ Microns	5.04	.950	28	0	$1.160 \times 10^{-3}$	—
$P_{ccombustion} = 658.2$ psia	5.84	1.100	35	0	$4.619 \times 10^{-4}$	—
Engine Type: 2V-3%	6.26	1.200	36	24	$6.277 \times 10^{-5}$	—
	7.125	1.350	37	37	$3.311 \times 10^{-5}$	—

Table 12

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		$P_o/P_c$	q (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 5.298 in.	0	0	0	0	$4.422 \times 10^{-3}$	—
D = 5.298 in.	2.12	.400	2	36	$1.088 \times 10^{-2}$	—
X/D = 1	3.15	.600	9	30	$8.256 \times 10^{-3}$	—
O/F = 6.0:1	4.24	.800	20	54	$2.981 \times 10^{-3}$	—
P <sub>ambient</sub> = 4.4 Microns	5.04	.950	28	0	$1.349 \times 10^{-3}$	—
P <sub>combustion</sub> = 606.5 psia	5.84	1.100	35	0	$5.614 \times 10^{-4}$	—
Engine Type: 2V-3%	6.26	1.200	36	24	$6.633 \times 10^{-5}$	—
	7.125	1.350	37	37	$6.194 \times 10^{-5}$	—

Table 13

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_0/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 5.298 in.	0	0	0	0	$3.819 \times 10^{-3}$	---
D = 5.298 in.	2.12	.400	2	36	$9.176 \times 10^{-3}$	---
X/D = 1	3.15	.600	9	30	$6.813 \times 10^{-3}$	---
O/F = 6.0:1	4.24	.800	20	54	$3.328 \times 10^{-3}$	---
$P_{ambient} = 2.8$ Microns	5.04	.950	28	0	$1.206 \times 10^{-3}$	---
$P_{combustion} = 658.1$ psia	5.84	1.100	35	0	$4.973 \times 10^{-4}$	---
Engine Type: 2V-3%	6.26	1.200	36	24	$3.146 \times 10^{-4}$	---
	7.125	1.350	37	37	$9.572 \times 10^{-5}$	---

Table 14

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	P <sub>o</sub> (in.)	R/D	θ		P <sub>o</sub> /P <sub>c</sub>	q (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 5.298 in.	0	0	0	0	4.263 x 10 <sup>-3</sup>	—
D = 5.298 in.	2.12	.400	2	36	1.659 x 10 <sup>-3</sup>	—
X/D = 1	3.15	.600	9	30	5.079 x 10 <sup>-4</sup>	—
O/F = 6.0:1	4.24	.800	20	54	3.049 x 10 <sup>-4</sup>	—
P <sub>ambient</sub> = 3.0 Microns	5.04	.950	28	0	1.486 x 10 <sup>-4</sup>	—
P <sub>combustion</sub> = 624.0 psia	5.84	1.100	35	0	9.390 x 10 <sup>-5</sup>	—
Engine Type: 2H-3%	6.26	1.200	36	24	1.020 x 10 <sup>-4</sup>	—
	7.125	1.350	37	37	3.634 x 10 <sup>-5</sup>	—

Table 15

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 5.298 in.	0	0	0	0	$3.297 \times 10^{-3}$	—
D = 5.298 in.	2.12	.400	2	36	$1.703 \times 10^{-3}$	—
X/D = 1	3.15	.600	4	30	$5.075 \times 10^{-4}$	—
O/F = 6.0:1	4.24	.800	20	54	$3.205 \times 10^{-4}$	—
$P_{ambient} = 5.0$ Microns	5.04	.950	28	0	$1.539 \times 10^{-4}$	—
$P_{combustion} = 627.6$ psia	5.84	1.100	35	0	$9.747 \times 10^{-5}$	—
Engine Type: 2H-3%	6.26	1.200	36	24	$9.476 \times 10^{-5}$	—
	7.125	1.350	37	37	$2.794 \times 10^{-5}$	—

Table 16

IBFF 3% Gener: Dynmice Booster/Separation Impingement Test (Plume Definition)					
Facility Parameters	R (in.)	R/D	$\theta$		$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)	
X = 5.298 in.	0	0	0	0	3.341 x 10 <sup>-2</sup>
D = 5.298 in.	2.12	.400	2	36	1.756 x 10 <sup>-3</sup>
X/D = 1	3.15	.600	9	30	4.842 x 10 <sup>-4</sup>
O/F = 6.0:1	4.24	.800	20	54	3.281 x 10 <sup>-4</sup>
P <sub>ambient</sub> = 4.0 Microns	5.04	.950	28	0	1.469 x 10 <sup>-4</sup>
P <sub>combustion</sub> = 623.1 psia	5.84	1.100	35	0	1.009 x 10 <sup>-4</sup>
Engine Type: 2H-3%	6.26	1.200	36	24	9.831 x 10 <sup>-5</sup>
	7.125	1.350	37	37	3.497 x 10 <sup>-5</sup>

Table 17

IBFF 3% General Dynamics Booster/Separator Impingement Test (Plume Definition)					
Facility Parameters	R (in.)	R/D	0		q (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)	
X = 5.298 in.	0	0	0	0	2.635 x 10 <sup>-3</sup>
D = 5.298 in.	2.12	.400	2	36	1.152 x 10 <sup>-3</sup>
X/D = 1	3.15	.600	9	30	4.526 x 10 <sup>-4</sup>
O/F = 6.0:1	4.24	.800	20	54	2.396 x 10 <sup>-4</sup>
P <sub>ambient</sub> = 4.0 Microns	5.04	.950	28	0	1.767 x 10 <sup>-4</sup>
P <sub>combustion</sub> = 612.8 psia	5.84	1.100	35	0	1.030 x 10 <sup>-4</sup>
Engine Type: 2H-3%	6.26	1.200	36	24	2.974 x 10 <sup>-6</sup>
	7.125	1.350	37	37	3.792 x 10 <sup>-5</sup>

Table 18

IBF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_0/P_\infty$	$\dot{q}$ (Btu/(ft <sup>2</sup> -sec))
			(deg)	(min.)		
X = 10.596 in.	0	0	0	0	$1.004 \times 10^{-2}$	—
D = 5.298 in.	2.55	.481	5	30	$2.694 \times 10^{-3}$	—
X/D = 2	3.75	.708	10	45	Out	—
O/F = 6.0:1	5.00	.944	17	12	$6.977 \times 10^{-4}$	—
$P_{\text{ambient}} = 5.0$ Microns	6.190	1.168	23	30	$3.269 \times 10^{-4}$	—
$P_{\text{combustion}} = 835.4$ psia	6.875	1.298	27	12	$2.433 \times 10^{-4}$	—
Engine Type: Equivalent	8.063	1.522	33	48	$1.139 \times 10^{-4}$	—
	9.375	1.770	37	30	$6.656 \times 10^{-5}$	—

Table 19

IBFF 3% General Dynamics Hooster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		$P'_0/P_c$	$\eta$ (lbm/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 10.596 in. D = 5.298 in. X/D = 2 O/F = 6.0:1 P <sub>ambient</sub> = 4.0 Microns P <sub>combustion</sub> = 549.5 psia Engine Type: Equivalent	0	0	0	0	$9.922 \times 10^{-3}$	—
	2.55	.481	5	30	$3.016 \times 10^{-3}$	—
	3.75	.708	10	45	$1.382 \times 10^{-3}$	—
	5.00	.944	17	12	$5.664 \times 10^{-4}$	—
	6.190	1.168	23	30	$3.082 \times 10^{-4}$	—
	6.875	1.298	27	12	$2.287 \times 10^{-4}$	—
	8.063	1.522	33	48	$1.306 \times 10^{-4}$	—
	9.375	1.770	37	30	$6.312 \times 10^{-5}$	—

Table 20

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P'_0/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 10.596 in.	0	0	0	0	$9.764 \times 10^{-3}$	—
D = 5.298 in.	2.55	.481	5	30	$3.198 \times 10^{-3}$	—
X/D = 2	3.75	.708	10	45	$1.484 \times 10^{-3}$	—
O/F = 6.0:1	5.00	.944	17	12	$7.853 \times 10^{-4}$	—
$P_{\text{ambient}} = 5.7$ Microns	6.190	1.168	23	30	$3.603 \times 10^{-4}$	—
$P_{\text{combustion}} = 667.6$ psia	6.875	1.298	27	12	$3.055 \times 10^{-4}$	—
Engine Type: Equivalent	8.063	1.522	33	48	$1.489 \times 10^{-4}$	—
	9.375	1.770	37	30	$9.603 \times 10^{-5}$	—

Table 21

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		$P_0/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 10.596 in.	0	0	0	0	$1.01 \times 10^{-2}$	—
D = 5.298 in.	2.55	.481	5	30	$3.419 \times 10^{-3}$	—
X/D = 2	3.75	.708	10	45	$1.366 \times 10^{-3}$	—
O/F = 6.0:1	5.00	.944	17	12	$6.464 \times 10^{-4}$	—
$P_{ambient} = 5.2$ Microns	6.190	1.168	23	30	$2.984 \times 10^{-4}$	—
$P_{combustion} = 543.4$ psia	6.875	1.298	27	12	$2.941 \times 10^{-4}$	—
Engine Type: Equivalent	8.063	1.522	33	48	$1.073 \times 10^{-4}$	—
	9.375	1.770	37	30	$7.186 \times 10^{-5}$	—

Table 22

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 10.596 in.	0	0	0	0	Out	—
D = 5.298 in.	1.25	.240	2	30	$6.839 \times 10^{-3}$	—
X/D = 2	1.75	.330	3	48	$5.603 \times 10^{-3}$	—
O/F = 6.0:1	2.48	.470	7	12	$3.647 \times 10^{-3}$	—
$P_{ambient} = 4.0$ Microns	7.50	1.420	30	0	$7.506 \times 10^{-5}$	—
$P_{combustion} = 671.3$ psia						
Engine Type: Equivalent						

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		P' / I <sub>c</sub>	q (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 10.596 in.	0	0	0	0	Out	_____
D = 5.298 in.	1.25	.240	2	30	8.985 x 10 <sup>-3</sup>	_____
X/D = 2	1.75	.330	3	48	6.653 x 10 <sup>-3</sup>	_____
O/F = 6.0:1	2.48	.470	7	12	3.808 x 10 <sup>-3</sup>	_____
P <sub>ambient</sub> = 5.0 Microns	7.50	1.420	30	0	7.988 x 10 <sup>-5</sup>	_____
P <sub>combustion</sub> = 636.0 psia						
Engine Type: Equivalent						

Table 24

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 10.596 in.	0	0	0	0	$1.052 \times 10^{-3}$	—
D = 5.298 in.	2.55	.481	5	30	Out	—
X/D = 2	3.75	.708	10	45	$3.234 \times 10^{-3}$	—
O/F = 6.0:1	5.00	.944	17	12	$1.263 \times 10^{-3}$	—
$P_{\text{ambient}} = 5.3$ Microns	6.190	1.168	23	30	$5.966 \times 10^{-4}$	—
$P_{\text{combustion}} = 528.9$ psia	6.875	1.298	27	12	$4.419 \times 10^{-4}$	—
Engine Type: 2V - 3%	8.063	1.522	33	48	$1.617 \times 10^{-4}$	—
	9.375	1.770	37	30	$6.656 \times 10^{-5}$	—

Table 25

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 10.596 in.	0	0	0	0	$3.187 \times 10^{-3}$	—
D = 5.298 in.	2.55	.481	5	30	Out	—
X/D = 2	3.75	.708	10	45	$2.716 \times 10^{-3}$	—
O/F = 6.0:1	5.00	.944	17	12	$1.246 \times 10^{-3}$	—
P <sub>ambient</sub> = 5.5 Microns	6.190	1.168	23	30	$5.554 \times 10^{-4}$	—
P <sub>combustion</sub> = 569.2 psia	6.875	1.298	27	12	$4.018 \times 10^{-4}$	—
Engine Type: 2V - 3%	8.063	1.522	33	48	$1.634 \times 10^{-4}$	—
	9.375	1.770	37	30	$7.159 \times 10^{-5}$	—

Table 26

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_i/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 10.596 in.	0	0	0	0	$2.827 \times 10^{-3}$	—
D = 5.298 in.	2.55	.481	5	30	Out	—
X/D = 2	3.75	.708	10	45	$3.526 \times 10^{-3}$	—
O/F = 6.0:1	5.00	.944	17	12	$1.166 \times 10^{-3}$	—
P <sub>ambient</sub> = 5.0 Microns	6.190	1.168	23	30	$6.176 \times 10^{-4}$	—
P <sub>combustion</sub> = 618.9 psia	6.875	1.298	27	12	$3.860 \times 10^{-4}$	—
Engine Type: 2V - 3%	8.063	1.522	33	48	$1.744 \times 10^{-4}$	—
	9.375	1.770	37	30	$7.509 \times 10^{-5}$	—

Table 27

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 10.596 in.	0	0	0	0	Out	—
D = 5.298 in.	1.25	.240	2	30	$3.337 \times 10^{-3}$	—
X/D = 2	2.48	.470	7	12	$6.738 \times 10^{-3}$	—
O/F = 6.0:1	7.50	1.420	30	0	Out	—
$P_{ambient} = 3.6$ Microns $P_{combustion} = 634.8$ psia Engine Type: 2V-3%						

Table 28

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		$P_o/P_c$	q (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 10.596 in.	0	0	0	0	Out	—
D = 5.298 in.	1.25	.24	2	30	$3.316 \times 10^{-3}$	—
X/D = 2	2.48	.47	7	12	$4.702 \times 10^{-3}$	—
O/F = 6.0:1	7.50	1.42	30	0	$3.256 \times 10^{-4}$	—
P <sub>ambient</sub> = 4.0 Microns P <sub>combustion</sub> = 590.9 psia Engine Type: 2V-3%						

Table 29

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P'_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 10.596 in.	0	0	0	0	$2.933 \times 10^{-3}$	—
D = 5.298 in.	2.55	.481	5	30	$1.677 \times 10^{-3}$	—
X/D = 2	3.75	.708	10	45	$6.623 \times 10^{-4}$	—
O/F = 6.0:1	5.00	.944	17	12	$2.711 \times 10^{-4}$	—
$P_{\text{ambient}} = 5.0$ Microns	6.190	1.168	23	30	$2.808 \times 10^{-4}$	—
$P_{\text{combustion}} = 614.9$ psia	6.875	1.298	27	12	$2.289 \times 10^{-4}$	—
Engine Type: 2H - 3%	8.063	1.522	33	48	$1.257 \times 10^{-4}$	—
	9.375	1.770	37	30	$7.059 \times 10^{-5}$	—

Table 30

IBBF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_\infty$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 10.596 in.	0	0	0	0	$2.957 \times 10^{-3}$	—
D = 5.298 in.	2.55	.481	5	30	$2.060 \times 10^{-3}$	—
X/D = 2	3.75	.708	10	45	$6.557 \times 10^{-4}$	—
O/F = 6.0:1	5.00	.944	17	12	$2.915 \times 10^{-4}$	—
$P_{\text{ambient}} = 5.5$ Microns	6.190	1.168	23	30	$2.836 \times 10^{-4}$	—
$P_{\text{combustion}} = 605.2$ psia	6.875	1.298	27	12	$2.183 \times 10^{-4}$	—
Engine Type: 2H - 3%	8.063	1.522	33	48	$1.181 \times 10^{-4}$	—
	9.375	1.770	37	30	$6.607 \times 10^{-5}$	—

Table 31

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	A		$P_o/P_c$	q (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 10.596 in.	0	0	0	0	$3.072 \times 10^{-3}$	—
D = 5.298 in.	2.55	.481	5	30	$1.889 \times 10^{-3}$	—
X/D = 2	3.75	.708	10	45	$7.619 \times 10^{-4}$	—
O/F = 6.0:1	5.00	.944	17	12	$4.863 \times 10^{-4}$	—
P <sub>ambient</sub> = 5.5 Microns	6.190	1.168	23	30	$2.723 \times 10^{-4}$	—
P <sub>combustion</sub> = 634.2 psia	6.875	1.298	27	12	$2.328 \times 10^{-4}$	—
Engine Type: 2H - 3%	9.375	1.770	37	30	$6.054 \times 10^{-5}$	—

Table 32

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		$P_i/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 10.596 in.	0	0	0	0	$2.982 \times 10^{-3}$	—
D = 5.298 in.	1.25	.240	2	30	$2.029 \times 10^{-3}$	—
X/D = 2	1.75	.330	3	48	$1.813 \times 10^{-3}$	—
O/F = 6.0:1	2.48	.470	7	12	$1.325 \times 10^{-3}$	—
P <sub>ambient</sub> = 2.2 Microns	7.50	1.420	30	0	$1.836 \times 10^{-4}$	—
P <sub>combustion</sub> = 839.8 psia						
Propellant Type: 2H-3%						

Table 33

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		$P_0/P_c$	q (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 10.596 in. D = 5.298 in. X/D = 2 O/F = 6.0:1 P <sub>ambient</sub> = 5.0 Microns P <sub>combustion</sub> = 601.7 psia Engine Type: 2H-3%	0	0	0	0	$2.463 \times 10^{-3}$	—
	1.25	.240	2	30	$1.439 \times 10^{-3}$	—
	1.75	.330	3	48	$1.429 \times 10^{-3}$	—
	2.48	.470	7	12	$1.109 \times 10^{-3}$	—
	7.50	1.420	30	0	$1.726 \times 10^{-4}$	—

Table 34

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_0/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 21.192 in.	0	0	0	0	$2.168 \times 10^{-3}$	—
D = 5.298 in.	2.50	.472	8	54	$2.166 \times 10^{-3}$	—
X/D = 4	5.00	.945	13	54	$5.617 \times 10^{-4}$	—
O/F = 6.0:1	7.50	1.416	18	24	$3.473 \times 10^{-4}$	—
$P_{\text{ambient}} = 3.0$ Microns	12.38	2.340	25	0	$8.566 \times 10^{-5}$	—
$P_{\text{combustion}} = 704.7$ psia	17.50	3.310	38	24	$7.107 \times 10^{-6}$	—
Engine Type: Equivalent	22.45	4.240	41	36	$8.36 \times 10^{-7}$	—

Table 35

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 21.192 in.	0	0	0	0	$2.118 \times 10^{-3}$	—
D = 5.298 in.	2.50	.472	8	54	$2.132 \times 10^{-3}$	—
X/D = 4	5.00	.945	13	54	$6.151 \times 10^{-4}$	—
O/F = 6.0:1	7.50	1.416	18	24	$3.485 \times 10^{-4}$	—
$P_{ambient} = 4.0$ Microns	12.38	2.340	25	0	$7.585 \times 10^{-5}$	—
$P_{combustion} = 541.6$ psia	17.50	3.310	38	24	$7.528 \times 10^{-6}$	—
Engine Type: Equivalent	22.45	4.240	41	36	$1.639 \times 10^{-6}$	—

Table 36

IBBF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		$P_0/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 21.192 in.	0	0	0	0	$2.259 \times 10^{-3}$	—
D = 5.298 in.	2.50	.472	8	54	$2.349 \times 10^{-3}$	—
X/D = 4	5.00	.945	13	54	$4.059 \times 10^{-4}$	—
O/F = 6.0:1	7.50	1.416	18	24	$3.288 \times 10^{-4}$	—
$P_{ambient} = 2.5$ Microns	12.38	2.340	25	0	$7.753 \times 10^{-5}$	—
$P_{combustion} = 592.7$ psia	17.50	3.310	38	24	Out	—
Engine Type: Equivalent	22.45	4.240	41	36	$1.470 \times 10^{-6}$	—

Table 37<sup>M</sup>

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 21.238 in.	0	0	0	0	$1.23 \times 10^{-3}$	—
D = 5.298 in.	2.50	.472	9	6	$2.36 \times 10^{-3}$	—
X/D = 4	5.00	.945	13	3	$1.04 \times 10^{-3}$	—
O/F = 6.0:1	7.50	1.416	18	35	$2.94 \times 10^{-4}$	—
$P_{ambient} = 1.0$ Micron	11.44	2.162	29	3	$6.49 \times 10^{-5}$	—
$P_{combustion} = 530.3$ psia	17.50	3.310	38	36	$5.57 \times 10^{-6}$	—
Engine Type: Equivalent	22.50	4.250	41	0	$1.54 \times 10^{-6}$	—
* Phase I						

Table 38\*

IEFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 21.238 in.	0	0	0	0	$4.505 \times 10^{-3}$	—
D = 5.298 in.	1.60	.302	5	36	$3.992 \times 10^{-3}$	—
X/D = 4	3.14	.593	10	50	$2.225 \times 10^{-3}$	—
O/F = 6.0:1	5.328	1.006	14	55	$7.905 \times 10^{-4}$	—
$P_{ambient} = 3.0$ Microns	7.421	1.401	18	30	$4.379 \times 10^{-4}$	—
$P_{combustion} = 504.0$ psia	13.645	2.576	31	0	$3.625 \times 10^{-5}$	—
Engine Type: Equivalent	18.515	3.495	40	20	—	2.5

\* Phase I

Table 39<sup>\*</sup>

IBBF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_i/P_c$	$\dot{q}$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 21.238 in.	0	0	0	0	$3.038 \times 10^{-3}$	—
D = 5.298 in.	1.60	.302	5	36	$2.904 \times 10^{-3}$	—
X/D = 4	3.14	.593	10	50	$2.160 \times 10^{-3}$	—
O/F = 6.0:1	5.328	1.006	14	55	$7.957 \times 10^{-4}$	—
P <sub>ambient</sub> = 5.0 Microns	7.421	1.401	18	30	$4.238 \times 10^{-4}$	—
P <sub>combustion</sub> = 557.8 psia	13.645	2.576	31	0	$5.205 \times 10^{-5}$	—
Engine Type: 2V - 3%	18.515	3.495	40	20	—	4.26

\* Phase I

Table 40<sup>a</sup>

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/(ft <sup>2</sup> -sec))
			(deg)	(min.)		
X = 21.192 in.	0	0	0	0	$2.691 \times 10^{-3}$	—
D = 5.298 in.	2.50	.472	8	54	$9.524 \times 10^{-4}$	—
X/D = 4	5.00	.945	13	54	$7.445 \times 10^{-4}$	—
O/F = 6.0:1	7.50	1.416	18	24	Out	—
$P_{ambient} = 5.2$ Microns	12.38	2.340	25	0	$1.145 \times 10^{-4}$	—
$P_{combustion} = 637.9$ psia	17.50	3.310	38	24	Out	—
Engine Type: 2V-3%	22.45	4.240	41	36	$1.639 \times 10^{-6}$	—

\*Phase I

Table 41\*

IBFF 3% General Dynamics Rooster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		$P_i/P_c$	q (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 21.192 in.	0	0	0	0	$3.680 \times 10^{-3}$	—
D = 5.298 in.	2.50	.472	8	54	$1.128 \times 10^{-3}$	—
X/D = 4	5.00	.945	13	54	$6.749 \times 10^{-4}$	—
O/F = 6.0:1	7.50	1.416	18	24	Out	—
$P_{\text{ambient}} = 5.5$ Microns	12.38	2.340	25	0	$9.774 \times 10^{-5}$	—
$P_{\text{combustion}} = 678.1$ psia	17.50	3.310	38	24	$1.178 \times 10^{-5}$	—
Engine Type: 2V-5%	22.45	4.240	41	36	$1.686 \times 10^{-6}$	—

\* Phase I

Table 42 \*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 21.192 in.	0	0	0	0	$2.565 \times 10^{-3}$	—
D = 5.298 in.	2.50	.472	8	54	$1.025 \times 10^{-3}$	—
X/D = 4	5.00	.945	13	54	$8.994 \times 10^{-4}$	—
O/F = 6.0:1	7.50	1.416	18	24	$4.609 \times 10^{-4}$	—
$P_{\text{ambient}} = 3.0$ Microns	12.38	2.340	25	0	$9.566 \times 10^{-5}$	—
$P_{\text{combustion}} = 804.5$ psia	17.50	3.310	38	24	Out	—
Engine Type: 2V-3%	22.45	4.240	41	36	$1.312 \times 10^{-6}$	—

\*Phase I

Table 43 \*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	q (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 21.238 in.	0	0	0	0	$4.19 \times 10^{-3}$	—
D = 5.298 in.	2.5	.472	9	6	$1.81 \times 10^{-3}$	—
X/D = 4	5.0	.945	13	3	$2.21 \times 10^{-3}$	—
O/F = 6.0:1	7.5	1.416	18	35	$4.53 \times 10^{-5}$	—
P <sub>ambient</sub> = 1.0 Micron	11.44	2.162	29	3	Out	—
P <sub>combustion</sub> = 639.1 psia	17.50	3.310	38	36	Out	—
Engine Type: 2V - 3%	22.5	4.250	41	0	Out	—
* Phase I						

Table 44 \*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P'/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 21.238 in.	0	0	0	0	$1.48 \times 10^{-3}$	—
D = 5.298 in.	2.50	.472	9	6	$1.74 \times 10^{-3}$	—
X/D = 4	5.00	.945	13	3	$5.02 \times 10^{-4}$	—
O/F = 6.0:1	7.50	1.416	18	35	$2.99 \times 10^{-5}$	—
$P_{\text{ambient}} = 1.0$ Micron	11.44	2.162	29	3	$7.94 \times 10^{-5}$	—
$P_{\text{combustion}} = 655.3$ psia	17.50	3.310	38	36	$7.66 \times 10^{-6}$	—
Engine Type: 2H - 3%	22.50	4.250	41	0	$2.81 \times 10^{-6}$	—

\* Phase I.

Table 45 \*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	6		$P_o/P_c$	q (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 21.192 in.	0	0	0	0	$3.103 \times 10^{-3}$	—
D = 5.298 in.	2.50	.472	8	54	$2.351 \times 10^{-3}$	—
X/D = 4	5.00	.945	13	54	$9.157 \times 10^{-4}$	—
O/F = 6.0:1	7.50	1.416	18	24	$3.603 \times 10^{-4}$	—
P <sub>ambient</sub> = 5.5 Microns	12.38	2.340	25	0	$1.075 \times 10^{-4}$	—
P <sub>combustion</sub> = 662.7 psia	17.50	3.310	38	24	Out	—
Engine Type: 2H - 3%	22.45	4.240	41	36	Out	—

\* Phase I

Table 46

IBFF 3% General Dynamics Booster/Separation Impingement Test. (Plume Definition)						
Facility Parameters	R (in.)	R/D	θ		P <sub>0</sub> /P <sub>c</sub>	q (Btu/ft <sup>2</sup> -sec)
			(deg)	(r/r <sub>0</sub> )		
X = 21.192 in.	0	0	0	0	3.244 x 10 <sup>-3</sup>	—
D = 5.298 in.	2.50	.472	8	54	2.442 x 10 <sup>-3</sup>	—
X/D = 4	5.00	.945	13	54	6.417 x 10 <sup>-4</sup>	—
O/F = 60:1	7.50	1.416	18	24	3.579 x 10 <sup>-4</sup>	—
P <sub>ambient</sub> = 6.0 Microns	12.38	2.340	25	0	1.159 x 10 <sup>-4</sup>	—
P <sub>combustion</sub> = 560.9 psia	17.50	3.310	38	24	Out	—
Engine Type: 2H-3%	22.45	4.240	41	36	Out	—

\* Phase I

\* Phase I

Table 47<sup>10</sup>

IBBF 3% General Dynamics Booster/Separation Impingement Test (Plane Definition)						
Facility Parameters	R (in.)	K/D	$\theta$		$P_0/P_c$	$\eta$ (lbm/ft <sup>2</sup> -sec)
			(deg)	(min)		
X = 21.192 in.	0	0	0	0	$2.760 \times 10^{-3}$	—
D = 5.293 in.	2.50	.472	8	54	$2.239 \times 10^{-3}$	—
X/D = 4	5.00	.945	13	54	$7.947 \times 10^{-4}$	—
O/F = 6.0:1	7.50	1.416	18	24	$4.139 \times 10^{-4}$	—
P <sub>ambient</sub> = 5.5 Microns	12.38	2.340	25	0	$1.289 \times 10^{-4}$	—
P <sub>combustion</sub> = 590.5 psia	17.50	3.310	38	24	Out	—
Engine Type: 2H - 3%	22.45	4.240	41	36	Out	—

\*Phase I

Table 48

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$ (deg)		$P^*/P_o$	$\dot{q}$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 21,238 in.	0	0	0	0	$3.537 \times 10^{-3}$	—
D = 5,298 in.	1.60	.302	5	36	$1.747 \times 10^{-3}$	—
X/D = 4	3.14	.593	10	50	$1.002 \times 10^{-3}$	—
C/F = 6.0:1	5.328	1.006	14	55	$9.638 \times 10^{-4}$	—
$\lambda_{\text{ambient}} = 3.0 \text{ microns}$	7.421	1.401	18	60	$6.872 \times 10^{-4}$	—
$P_{\text{combustion}} = 596.1 \text{ psia}$	13.645	2.576	31	0	$1.825 \times 10^{-5}$	—
Engine Type: 2H - 3%	18.515	3.495	40	20	—	6.8

\*Phase 1

Table 49

IBBF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		$\frac{p_0}{p_\infty}$	$\frac{q}{\rho a^2}$ (lbm/ft <sup>2</sup> -sec)
			(deg)	(min)		
X = 52.98 in.	0	0	0	0	1.409x10 <sup>-4</sup>	—
D = 5.298 in.	4.65	.50	3	30	2.544x10 <sup>-4</sup>	—
X/D = 10	5.30	1.00	6	54	1.506x10 <sup>-4</sup>	—
O/F = 6.0:1	7.36	1.39	10	5	2.357x10 <sup>-4</sup>	—
P <sub>ambient</sub> = 3.0 microns	9.23	1.75	12	5	2.771x10 <sup>-4</sup>	—
P <sub>combustion</sub> = 595.3 psia	17.50	3.30	21	0	Out	—
Engine Type: Equivalent	21.23	4.00	24	0	Out	—
	23.92	4.50	25	6	Out	—

Table 50

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min)		
X = 52.93 in.	0	0	0	0	$1.393 \times 10^{-4}$	—
D = 5.298 in.	17.500	3.30	21	0	Out	—
X/D = 10	21.125	3.99	23	48	$5.808 \times 10^{-5}$	—
O/F = 6.0:1	23.437	4.40	25	6	$2.852 \times 10^{-5}$	—
$P_{ambient} = 3.0$ microns	26.375	4.98	27	30	$2.465 \times 10^{-5}$	—
$P_{combustion} = 596.8$	29.125	5.50	28	58	$1.296 \times 10^{-5}$	—
Engine Type: Equivalent	31.562	5.96	31	36	$1.079 \times 10^{-5}$	—
	35.750	6.76	35	0	$5.677 \times 10^{-6}$	—

Table 51

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		P <sub>0</sub> /P <sub>c</sub>	q (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 52.98 in.	0	0	0	0	2.362x10 <sup>-4</sup>	—
D = 5.298 in.	2.65	.50	3	30	2.381x10 <sup>-4</sup>	—
X/D = 10	5.30	1.00	6	54	1.927x10 <sup>-4</sup>	—
O/F = 6.0:1	7.36	1.39	10	5	3.524x10 <sup>-4</sup>	—
P <sub>ambient</sub> = 3.0 microns	9.25	1.75	12	5	8.830x10 <sup>-5</sup>	—
P <sub>combustion</sub> = 536.7 psia	17.50	3.30	21	0	8.289x10 <sup>-5</sup>	—
Engine Type: Equivalent	21.20	4.00	24	0	2.985x10 <sup>-5</sup>	—
	23.92	4.50	25	6	2.819x10 <sup>-5</sup>	—

Table 52

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_i/P_o$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 52.98 in. D = 5.298 in. X/D = 10 O/F = 6.0:1 P <sub>ambient</sub> = 3.0 Microns P <sub>combustion</sub> = 598.6 psia Engine Type: Equivalent	0	0	0	0	$1.417 \times 10^{-4}$	—
	17.500	3.30	21	0	$7.158 \times 10^{-5}$	—
	21.125	3.99	23	48	$4.494 \times 10^{-5}$	—
	23.435	4.40	25	6	$2.340 \times 10^{-5}$	—
	26.375	4.98	27	30	$1.888 \times 10^{-5}$	—
	29.125	5.50	28	58	$8.002 \times 10^{-6}$	—
	31.562	5.96	31	36	$8.419 \times 10^{-6}$	—
	35.750	6.76	35	0	$4.291 \times 10^{-6}$	—

Table 53

IBFF 3% General Dynamics Booster/Separation In-pingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		$P_0/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 52.98 in.	0	0	0	0	$2.458 \times 10^{-4}$	—
D = 5.298 in.	2.65	.50	3	30	$2.626 \times 10^{-4}$	—
X/D = 10	5.30	1.00	6	54	Out	—
C/F = 6.0:1	7.95	1.50	9	48	$1.701 \times 10^{-4}$	—
$P_{ambient} = 0$ microns	10.29	1.94	13	30	$1.213 \times 10^{-4}$	—
$P_{combustion} = 708.5$ psia	17.45	3.30	21	0	$6.447 \times 10^{-5}$	—
Engine Type. 2V - 3%	21.17	4.00	23	48	$2.959 \times 10^{-5}$	—
	23.27	4.40	25	6	$1.358 \times 10^{-5}$	—

Table 54

IBFF 3% General Dynamics Booster/Separation Impingement Test: (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec.)
			(deg)	(min.)		
X = 52.98 in.	0	0	0	0	$2.866 \times 10^{-4}$	—
D = 5.298 in.	17.500	3.30	21	0	Out	—
X/D = 10	21.125	3.99	23	48	$3.402 \times 10^{-5}$	—
O/F = 6.0:1	23.437	4.40	25	6	$1.413 \times 10^{-5}$	—
P <sub>ambient</sub> = 5.0 Microns	26.375	4.98	27	30	$1.468 \times 10^{-5}$	—
P <sub>combustion</sub> = 682.9 psia	29.125	5.50	28	58	$6.298 \times 10^{-6}$	—
Engine Type: 2V - 3%	31.562	5.96	31	36	$5.696 \times 10^{-6}$	—
	35.750	6.76	35	0	$3.055 \times 10^{-6}$	—

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IBF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		$P_o/P_c$	q (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 52.98 in.	0	0	0	0	$1.671 \times 10^{-4}$	—
D = 5.298 in.	2.65	.50	3	30	$2.475 \times 10^{-4}$	—
X/D = 10	5.30	1.00	6	54	$2.635 \times 10^{-4}$	—
O/F = 6.0:1	7.95	1.50	9	48	$1.275 \times 10^{-4}$	—
$P_{ambient} = 2.0$	10.29	1.94	13	30	$1.082 \times 10^{-4}$	—
$P_{combustion} = 731.7$ psia	17.45	3.30	21	0	$6.561 \times 10^{-5}$	—
Engine Type: 2V - 3%	21.17	4.00	23	48	$4.196 \times 10^{-5}$	—
	23.27	4.40	25	6	$2.351 \times 10^{-5}$	—

Table 56

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 52.98 in.	0	0	0	0	$2.438 \times 10^{-4}$	—
D = 5.298 in.	17,500	3.30	21	0	Out	—
X/D = 10	21,125	3.99	23	48	$3.482 \times 10^{-5}$	—
O/F = 6.0:1	23,437	4.40	25	6	$1.418 \times 10^{-5}$	—
$P_{\text{ambient}} = 3.0$ Microns	26,375	4.98	27	30	$1.111 \times 10^{-5}$	—
$P_{\text{combustion}} = 669.6$ psia	29,125	5.50	28	58	$4.193 \times 10^{-6}$	—
Engine Type: 2V - 3%	31,562	5.96	31	36	$5.571 \times 10^{-6}$	—
	35,750	6.76	35	0	$2.727 \times 10^{-6}$	—

Table 57

IBFI 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		$P_0/P_c$	$\dot{q}$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 52.98 in.	0	0	0	0	$2.663 \times 10^{-4}$	—
D = 5.298 in.	2.65	.50	3	30	$2.680 \times 10^{-4}$	—
X/D = 10	5.30	1.00	6	50	$2.382 \times 10^{-4}$	—
O/F = 6.0:1	7.36	1.33	10	5	$3.609 \times 10^{-4}$	—
F <sub>ambient</sub> = 5.0 Microns	9.25	1.75	12	5	$2.035 \times 10^{-4}$	—
P <sub>combustion</sub> = 618.7 psia	17.50	3.30	21	0	$1.259 \times 10^{-4}$	—
Engine Type: 2H - 3%	21.23	4.00	24	0	$9.102 \times 10^{-5}$	—
	23.92	4.50	25	0	$5.639 \times 10^{-5}$	—

Table 58

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 52.98 in.	0	0	0	0	$2.006 \times 10^{-4}$	—
D = 5.298	17.500	3.30	21	0	Out	—
X/D = 10	21.125	3.99	23	48	$6.757 \times 10^{-5}$	—
O/F = 6.0:1	23.437	4.40	25	6	$3.438 \times 10^{-5}$	—
$P_{ambient} = 3.2$ Microns	26.375	4.98	27	30	$2.583 \times 10^{-5}$	—
$P_{combustion} = 675.4$ psia	29.125	5.50	28	58	$1.539 \times 10^{-5}$	—
Engine Type: 2H - 3%	31.562	5.96	31	36	$1.739 \times 10^{-5}$	—
	35.750	6.76	35	0	Out	—

Table 59

IBF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 52.98 in.	0	0	0	0	$2.776 \times 10^{-4}$	—
D = 5.298 in.	2.65	.50	3	30	$3.019 \times 10^{-4}$	—
X/D = 10	5.30	1.00	6	54	$2.582 \times 10^{-4}$	—
O/F = 6.0:1	7.36	1.39	10	5	Out	—
$P_{ambient} = 5.5$ Microns	9.25	1.75	12	5	$1.749 \times 10^{-4}$	—
$P_{combustion} = 26.7$ psia	17.50	3.30	21	0	$8.750 \times 10^{-5}$	—
Engine Type: 2H - 3%	21.23	4.00	24	0	$5.374 \times 10^{-5}$	—
	23.92	4.50	25	6	$4.669 \times 10^{-5}$	—

Table 60

IBFF 3% General Dynamics Booster/Separation Impingement Test (Phase Definition)					
Facility Parameters	R (in.)	R/D	$\theta$		$P_0/P_\infty$ (lb./sq. in.)
			(deg)	(min.)	
X = 52.98 in.	0	0	0	0	$2.155 \times 10^{-4}$
D = 5.298 in.	17.500	3.30	21	0	Out
X/D = 10	21.125	3.99	23	48	$8.387 \times 10^{-5}$
O/F = 6.0:1	23.437	4.40	25	6	$5.474 \times 10^{-5}$
$P_{ambient} = 5.0$ Microns	26.375	4.98	27	30	$3.671 \times 10^{-5}$
$P_{combustion} = 682.1$ psia	29.125	5.50	28	58	$2.127 \times 10^{-5}$
Engine Type: 2H - 3%	31.562	5.96	31	36	$2.065 \times 10^{-5}$
	35.750	6.76	35	0	$1.155 \times 10^{-5}$

Table 61

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P'_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 63.58 in.	0	0	0	0	---	51.3
D = 5.298 in.	2.7	.5	2	44	$1.66 \times 10^{-4}$	---
X/D = 12	6.3	1.2	6	33	$1.11 \times 10^{-4}$	---
O/F = 6.0:1	8.5	1.6	9	10	$1.45 \times 10^{-4}$	---
P <sub>ambient</sub> = 2.0 Microns	14.5	2.7	14	20	$1.14 \times 10^{-4}$	---
P <sub>combustion</sub> = 577.2 psia	17.5	3.3	18	3	$9.88 \times 10^{-5}$	---
Engine Type: Equivalent	21.2	4.0	21	4	$4.30 \times 10^{-5}$	---
	23.8	4.5	22	56	$2.13 \times 10^{-6}$	---

\*Phase I

Table 62

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 63.58 in. D = 5.298 in. X/D = 12 O/F = 6.0:1 P <sub>ambient</sub> = 7.0 Microns P <sub>combustion</sub> = 656.5 psia Engine Type: 2V - 3%  * Phase I	0	0	0	0	$1.87 \times 10^{-4}$	—
	2.7	.5	2	44	$2.18 \times 10^{-4}$	—
	6.3	1.2	6	33	$1.54 \times 10^{-4}$	—
	8.5	1.6	9	10	$1.61 \times 10^{-4}$	—
	14.5	2.7	14	20	$6.17 \times 10^{-5}$	—
	17.5	3.3	18	3	$5.28 \times 10^{-5}$	—
	21.2	4.0	21	4	$2.99 \times 10^{-5}$	—
	23.8	4.5	22	56	$1.07 \times 10^{-6}$	—

Table 63

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)					
Facility Parameters	R (in.)	R/D	$\theta$		$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)	
X = 63.58 in.	0	0	0	0	1.85 x 10 <sup>-4</sup>
D = 5.298 in.	17.50	3.30	18	3	5.35 x 10 <sup>-5</sup>
X/D = 12	21.20	4.00	21	4	3.01 x 10 <sup>-5</sup>
O/F = 6.0:1	23.80	4.50	22	56	7.63 x 10 <sup>-7</sup>
P <sub>ambient</sub> = 4.5 Microns	26.40	5.00	24	57	1.12 x 10 <sup>-5</sup>
P <sub>combustion</sub> = 658.4 psia	29.10	5.50	25	40	Out
Engine Type: 2V - 3%	31.75	6.00	27	35	5.21 x 10 <sup>-6</sup>
	35.75	6.76	29	57	2.18 x 10 <sup>-6</sup>

\*Phase I

Table 64

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 63.58 in. D = 5.298 in. X/D = 12 O/F = 6.0:1 P <sub>ambient</sub> = 2.0 Microns P <sub>combustion</sub> = 620.6 psia Engine Type. 2H - 3 %	0	0	0	0	—	60.3
	2.7	.5	2	44	$1.99 \times 10^{-4}$	—
	6.3	1.2	6	33	$1.51 \times 10^{-4}$	—
	8.5	1.6	9	10	$1.64 \times 10^{-4}$	—
	14.5	2.7	14	20	$1.41 \times 10^{-4}$	—
	17.5	3.3	18	3	$1.12 \times 10^{-4}$	—
	21.2	4.0	21	4	$6.29 \times 10^{-5}$	—
	23.8	4.5	22	56	$2.02 \times 10^{-6}$	—
*Phase I						

Table 65\*

IBEF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_0/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	—	Q <sub>gt</sub>
D = 5.298 in.	2.55	.481	2	6	$1.077 \times 10^{-4}$	—
X/D = 15	5.20	.981	4	18	$1.096 \times 10^{-4}$	—
O/F = 6.0:1	7.90	1.491	6	30	$9.806 \times 10^{-5}$	—
P <sub>ambient</sub> = 6.8 Microns	10.50	1.982	8	24	$1.064 \times 10^{-4}$	—
P <sub>combustion</sub> = 608.8 psia	15.89	2.999	13	12	$7.38 \times 10^{-5}$	—
Engine Type: Equivalent	18.45	3.482	15	24	$7.85 \times 10^{-5}$	—
	21.30	4.001	16	36	$7.13 \times 10^{-5}$	—
	23.79	4.490	18	36	—	29.1

\* Phase I

Table 66\*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		$P_0/P_c$	$\dot{q}$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	—	41.9
D = 5.298 in.	2.55	.481	2	6	$1.100 \times 10^{-4}$	—
X/D = 15	5.20	.981	4	18	$1.161 \times 10^{-4}$	—
O/F = 6.0:1	7.90	1.491	6	30	$1.063 \times 10^{-4}$	—
$P_{\text{ambient}} = 6.0$ Microns	10.50	1.982	8	24	$1.066 \times 10^{-4}$	—
$P_{\text{combustion}} = 542.6$ psia	15.89	2.999	13	12	$9.113 \times 10^{-5}$	—
Engine Type: Equivalent	18.45	3.482	15	24	$8.403 \times 10^{-5}$	—
	21.30	4.001	16	36	$7.625 \times 10^{-5}$	—
	23.79	4.490	18	36	—	29.8
*Phase I						

Table 67\*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P'_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	$9.61 \times 10^{-5}$	—
D = 5.298 in.	2.7	.5	2	1	$6.71 \times 10^{-5}$	—
X/D = 15	5.3	1.0	4	45	$2.80 \times 10^{-5}$	—
O/F = 6.0:1	7.9	1.5	6	24	$9.86 \times 10^{-5}$	—
$P_{ambient} = 1.0$ Micron	10.6	2.0	8	23	$9.21 \times 10^{-5}$	—
$P_{combustion} = 527.3$ psia	18.5	3.5	15	44	$8.33 \times 10^{-5}$	—
Engine Type: Equivalent	21.2	4.0	16	44	$5.52 \times 10^{-5}$	—
	23.8	4.5	19	9	$2.66 \times 10^{-6}$	—

\*Phase I

Table 68

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o'/P_o$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	$1.060 \times 10^{-4}$	—
D = 5.298 in.	2.65	.5	2	0	Out	—
X/D = 15	5.30	1.0	4	12	$1.229 \times 10^{-4}$	—
O/F = 6.0:1	7.95	1.5	6	30	$7.296 \times 10^{-5}$	—
$P_{\text{ambient}} = 5.0$ Microns	10.60	2.0	8	24	$7.379 \times 10^{-5}$	—
$P_{\text{combustion}} = 607.6$ psia	18.54	3.5	15	24	$6.715 \times 10^{-5}$	—
Engine Type: Equivalent	21.20	4.0	16	36	$1.271 \times 10^{-4}$	—
	23.84	4.5	18	36	$6.729 \times 10^{-5}$	—

Table 69

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in. D = 5.298 in. X/D = 15 O/F = 6.0:1 P <sub>ambient</sub> = 3.0 Microns P <sub>combustion</sub> = 604.3 psia Engine Type: Equivalent	0	0	0	0	$1.034 \times 10^{-4}$	—
	18.540	3.50	15	24	$4.248 \times 10^{-5}$	—
	21.187	4.00	16	36	$6.686 \times 10^{-5}$	—
	23.812	4.50	18	36	$6.065 \times 10^{-5}$	—
	26.500	5.00	20	54	Out	—
	29.187	5.50	22	24	$3.461 \times 10^{-5}$	—
	31.750	6.00	24	24	$2.211 \times 10^{-5}$	—
	35.750	6.76	25	30	$1.525 \times 10^{-5}$	—

Table 70

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	$9.064 \times 10^{-5}$	—
D = 5.298 in.	2.65	.5	2	0	Out	—
X/D = 15	5.30	1.0	4	12	$9.571 \times 10^{-5}$	—
O/F = 6.0:1	7.95	1.5	6	30	$6.666 \times 10^{-5}$	—
$P_{\text{ambient}} = 10.0$ Microns	10.60	2.0	8	24	$7.876 \times 10^{-5}$	—
$P_{\text{combustion}} = 604.1$ psia	18.54	3.5	15	24	$6.942 \times 10^{-5}$	—
Engine Type: Equivalent	21.20	4.0	16	36	$1.113 \times 10^{-4}$	—
	23.84	4.5	18	36	$6.801 \times 10^{-5}$	—

Table 71

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P'_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	$1.005 \times 10^{-4}$	—
D = 5.298 in.	18.54	3.50	15	24	$4.911 \times 10^{-5}$	—
X/D = 15	21.187	4.00	16	36	$6.798 \times 10^{-5}$	—
O/F = 6.0:1	23.812	4.50	18	36	$6.490 \times 10^{-5}$	—
P <sub>ambient</sub> = 3.0	26.500	5.00	20	54	$2.918 \times 10^{-5}$	—
P <sub>combustion</sub> = 638.0 psia	29.187	5.50	22	24	$4.609 \times 10^{-5}$	—
Engine Type: Equivalent	31.750	6.00	24	24	$2.563 \times 10^{-5}$	—
	35.750	6.76	25	30	$1.518 \times 10^{-5}$	—

Table 72\*

IEEF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_i/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	—	52.8
D = 5.298 in.	2.55	.481	2	6	$1.172 \times 10^{-4}$	—
X/D = 15	5.20	.981	4	18	$1.399 \times 10^{-4}$	—
O/F = 6.0:1	7.90	1.491	6	30	$1.223 \times 10^{-4}$	—
$P_{\text{ambient}} = 5.8$ Microns	10.50	1.982	8	24	$1.202 \times 10^{-4}$	—
$P_{\text{combustion}} = 534.4$ psia	15.89	2.999	13	18	$6.970 \times 10^{-5}$	—
Engine Type: 2V - 3%	18.45	3.482	15	24	$4.631 \times 10^{-5}$	—
	21.30	4.001	16	36	$4.339 \times 10^{-5}$	—
	23.79	4.490	18	36	—	16.2

\* Phase I

Table 73 \*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P'_0/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in. D = 5.298 in. X/D = 15 O/F = 6.0:1 P <sub>ambient</sub> = 1.0 Microns P <sub>combustion</sub> = 697.4 psia Engine Type: 2V - 3%	0	0	0	0	$9.61 \times 10^{-5}$	—
	2.7	.5	2	1	$6.71 \times 10^{-5}$	—
	5.3	1.0	4	45	$2.80 \times 10^{-5}$	—
	7.9	1.5	6	24	$9.86 \times 10^{-5}$	—
	10.6	2.0	8	23	$9.21 \times 10^{-5}$	—
	18.5	3.5	15	44	$8.33 \times 10^{-5}$	—
	21.2	4.0	16	44	$5.52 \times 10^{-5}$	—
	23.8	4.5	19	9	$2.66 \times 10^{-6}$	—
*Phase I						

Table 74\*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P'_0/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in. D = 5.298 in. X/D = 15 O/F = 6.0:1 P <sub>ambient</sub> = 2.0 Microns P <sub>combustion</sub> = 661.5 psia Engine Type: 2V - 3%	0	0	0	0	$1.37 \times 10^{-4}$	—
	18.50	3.5	15	32	$3.91 \times 10^{-5}$	—
	21.20	4.0	16	53	$2.33 \times 10^{-5}$	—
	23.80	4.5	19	0	$1.33 \times 10^{-6}$	—
	26.40	5.0	20	50	$2.48 \times 10^{-5}$	—
	29.10	5.5	22	34	$1.12 \times 10^{-5}$	—
	31.75	6.0	24	0	$1.29 \times 10^{-5}$	—
	35.75	6.76	25	35	$1.51 \times 10^{-5}$	—
*Phase I.						

Table 75

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P'_0/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in. D = 5.298 in. X/D = 15 O/F = 6.0:1 P <sub>ambient</sub> = 5.0 Microns P <sub>combustion</sub> = 757.5 psia Engine Type: 2H - 3%	0	0	0	0	$1.066 \times 10^{-4}$	—
	2.65	.5	2	0	$1.522 \times 10^{-4}$	—
	5.375	1.0	4	12	$1.189 \times 10^{-4}$	—
	18.540	3.5	15	24	$8.793 \times 10^{-5}$	—
	21.200	4.0	16	36	$7.181 \times 10^{-5}$	—
	23.840	4.5	18	36	$7.099 \times 10^{-5}$	—
	26.450	5.0	20	54	$5.205 \times 10^{-5}$	—
	29.250	5.5	22	24	$2.752 \times 10^{-5}$	—

Table 76

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		$P'_0/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	$9.423 \times 10^{-5}$	—
D = 5.298 in.	17.500	3.30	21	0	$5.923 \times 10^{-5}$	—
X/D = 15	21.125	3.99	23	4	$7.848 \times 10^{-5}$	—
O/F = 6.0:1	23.435	4.40	25	6	$7.929 \times 10^{-5}$	—
$P_{\text{ambient}} = 3.0$ Microns	26.375	4.98	27	30	$5.135 \times 10^{-5}$	—
$P_{\text{combustion}} = 725.0$	29.125	5.50	28	58	$5.173 \times 10^{-5}$	—
Engine Type: 2H - 3%	31.562	5.96	31	36	$3.337 \times 10^{-5}$	—
	35.750	6.76	35	0	$2.370 \times 10^{-5}$	—

Table 77

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in. D = 5.298 in. X/D = 15 O/F = 6.0:1 P <sub>ambient</sub> = 2.0 Microns P <sub>combustion</sub> = 725.9 psia Engine Type: 2H - 3%	0	0	0	0	$9.045 \times 10^{-5}$	—
	2.650	.5	2	0	$1.221 \times 10^{-4}$	—
	5.375	1.0	4	12	$1.003 \times 10^{-4}$	—
	18.540	3.5	15	24	$8.582 \times 10^{-5}$	—
	21.200	4.0	16	36	$7.846 \times 10^{-5}$	—
	23.840	4.5	18	36	$7.592 \times 10^{-5}$	—
	26.450	5.0	20	54	$6.170 \times 10^{-5}$	—
	29.250	5.5	22	24	$1.894 \times 10^{-5}$	—

Table 78

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P'_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	$8.709 \times 10^{-5}$	—
D = 5.298 in.	18.540	3.50	15	24	$5.344 \times 10^{-5}$	—
X/D = 15	21.187	4.00	16	36	$7.382 \times 10^{-5}$	—
O/F = 6.0:1	23.812	4.50	18	36	$5.879 \times 10^{-5}$	—
$P_{ambient} = 3.0$ Microns	26.500	5.00	20	54	$3.964 \times 10^{-5}$	—
$P_{combustion} = 737.9$ psia	29.187	5.50	22	24	$4.278 \times 10^{-5}$	—
Engine Type: 2H - 3%	31.750	6.00	24	24	$2.957 \times 10^{-5}$	—
	35.750	6.75	25	30	$3.117 \times 10^{-5}$	—

Table 79\*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	$8.23 \times 10^{-5}$	—
D = 5.298 in.	18.50	3.50	15	32	$7.60 \times 10^{-5}$	—
X/D = 15	21.20	4.00	16	53	$4.73 \times 10^{-5}$	—
O/F = 6.0:1	23.80	4.50	19	0	$2.54 \times 10^{-6}$	—
$P_{\text{ambient}} = 2.1$ Microns	26.40	5.00	20	50	$3.61 \times 10^{-5}$	—
$P_{\text{combustion}} = 434.8$ psia	29.10	5.50	22	34	$4.33 \times 10^{-6}$	—
Engine Type: 2H - 3%	31.75	6.00	24	0	$1.10 \times 10^{-5}$	—
	35.75	6.76	25	35	$9.71 \times 10^{-6}$	—
*Phase I						

Table 80\*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P'_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	—	101.8
D = 5.298 in.	2.55	.481	2	6	$1.147 \times 10^{-4}$	—
X/D = 15	5.20	.981	4	18	$1.468 \times 10^{-4}$	—
O/F = 6.0:1	7.90	1.491	6	30	$1.352 \times 10^{-4}$	—
P <sub>ambient</sub> = 5.0 Microns	10.50	1.982	8	24	$1.298 \times 10^{-4}$	—
P <sub>combustion</sub> = 567.6 psia	15.89	2.999	13	12	$1.129 \times 10^{-4}$	—
Engine Type: 2H - 3%	18.45	3.482	15	24	$1.054 \times 10^{-4}$	—
	21.30	4.001	16	36	$9.088 \times 10^{-5}$	—
	23.79	4.490	18	36	—	27.3

\*Phase I

Table 81\*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	q (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.4 in. D = 5.298 in. X/D = 15 O/F = 6.0:1 P <sub>ambient</sub> = 1.0 Microns P <sub>combustion</sub> = 653.3 psia Engine Type: 2H - 3%	0	0	0	0	—	41.4
	2.7	.5	2	1	$5.99 \times 10^{-5}$	—
	5.3	1.0	4	45	$4.57 \times 10^{-5}$	—
	7.9	1.5	6	24	$1.16 \times 10^{-4}$	—
	10.6	2.0	8	23	$1.07 \times 10^{-4}$	—
	18.5	3.5	15	44	$8.19 \times 10^{-5}$	—
	21.2	4.0	16	44	$4.68 \times 10^{-5}$	—
	23.8	4.5	19	9	$2.25 \times 10^{-6}$	—

\*Phase I

Table 82 \*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	q (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.4 in.	0	0	0	0	—	37.7
D = 5.298 in.	18.50	3.5	15	32	$7.29 \times 10^{-5}$	—
X/D = 15	21.20	4.0	16	53	$4.91 \times 10^{-5}$	—
O/F = 6.0:1	23.80	4.5	19	0	$2.09 \times 10^{-6}$	—
P <sub>ambient</sub> = 2.0 Microns	26.40	5.0	20	50	$4.98 \times 10^{-5}$	—
P <sub>combustion</sub> = 646.6 psia	29.10	5.5	23	34	$1.58 \times 10^{-5}$	—
Engine Type: 2H- 3%	31.75	6.0	24	0	$3.29 \times 10^{-5}$	—
	35.75	6.76	25	35	$1.83 \times 10^{-5}$	—

\* Phase I

Table 83

## PLUME IMPACT HEATING RATE SURVEYS

Table No.	X/D	Engine Config.	Run No.	Symbol	P <sub>c</sub> (psia)	P <sub>∞</sub> (μHg)
84	4.0	1	6/0*	■	504.0	3.0
85	4.0	2V	5/0*	◈	557.8	5.0
86	4.0	2H	4/0*	●	596.1	3.0
87	10.0	1	11/0	■	532.6	5.5
88	10.0	1	11/1	□	566.5	5.5
89	10.0	1	12/0	◻	601.7	5.5
90	10.0	1	13/0	◻	629.7	4.0
91	10.0	2V	25/0	◈	718.4	5.0
92	10.0	2V	26/0	◈	684.6	5.5
93	10.0	2H	47/0	●	726.2	5.2
94	10.0	2H	48/0	○	709.3	3.0
95	12.0	1	58/0*	□	577.2	2.0
96	12.0	2H	60/0*	○	620.6	2.0
97	15.0	1	1/5*	◻	608.8	6.8
98	15.0	1	1/6*	■	542.6	6.0
99	15.0	1	13/0	□	629.7	4.0
100	15.0	1	52/0*	◻	557.3	1.0
101	15.0	1	53/0*	◻	566.2	1.0
102	15.0	1	14/0	◼	610.7	2.5
103	15.0	2V	2/0*	◈	534.4	5.8
104	15.0	2V	23/0	◈	703.4	4.5
105	15.0	2V	24/0	◈	715.8	4.2
106	15.0	2V	25/0	◈	718.4	5.0

\*Phase I

Table 33 (Continued)

## PLUME IMPACT HEATING RATE SURVEYS

Table No.	X/D	Engine Config.	Run No.	Symbol	P <sub>c</sub> (psia)	P <sub>∞</sub> (μHg)
107	15.0	2V	26/0	◊	684.6	5.5
108	15.0	2H	3/1*	●	567.6	5.0
109	15.0	2H	49/0	○	735.7	3.5
110	15.0	2H	50/0	○	719.9	4.5
111	15.0	2H	54/0*	○	653.3	1.0
112	15.0	2H	55/0*	●	646.6	2.0

\*Phase I

Table 84 \*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	θ		$P'_0/P_c$	$\dot{q}_i$ ( $Etu/\dot{V}_i^2\text{-sec}$ )
			(deg)	(min.)		
X = 21.238 in.	0	0	0	0	$4.505 \times 10^{-3}$	—
D = 5.298 in.	1.60	.302	5	36	$3.992 \times 10^{-3}$	—
X/D = 4	3.14	.593	10	50	$2.225 \times 10^{-3}$	—
O/F = 6.0:1	5.328	1.006	14	55	$7.905 \times 10^{-4}$	—
$P_{\text{ambient}} = 3.0$ Microns	7.421	1.401	18	30	$4.379 \times 10^{-4}$	—
$P_{\text{combustion}} = 504.0$ psia	13.645	2.576	31	0	$3.625 \times 10^{-5}$	—
Engine Type: Equivalent	18.515	3.495	40	20	—	2.5
*Phase I						

Table 85 \*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/P	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 21.238 in.	0	0	0	0	$3.038 \times 10^{-3}$	—
D = 5.298 in.	1.60	.302	5	36	$2.904 \times 10^{-3}$	—
X/D = 4	3.14	.593	10	50	$2.160 \times 10^{-3}$	—
O/F = 6.0:1	5.328	1.006	14	55	$7.957 \times 10^{-4}$	—
$P_{\text{ambient}} = 5.0$ Microns	7.421	1.401	18	30	$4.238 \times 10^{-4}$	—
$P_{\text{combustion}} = 557.8$ psia	13.645	2.576	31	0	$5.205 \times 10^{-5}$	—
Engine Type: 2V - 3%	18.515	3.495	40	20	—	4.26

\*Phase I

Table 86\*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$ (deg)		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			$\theta$	(min.)		
X = 21.238 in.	0	0	0	0	$3.537 \times 10^{-3}$	—
D = 5.298 in.	1.60	.302	5	36	$1.747 \times 10^{-3}$	—
X/D = 4	3.14	.593	10	50	$1.002 \times 10^{-3}$	—
O/F = 6.0:1	5.328	1.006	14	55	$9.638 \times 10^{-4}$	—
$P_{ar}$ ent = 3.0 Microns	7.421	1.401	18	30	$6.872 \times 10^{-4}$	—
$P_{combustion}$ = 596.1 psia	13.645	2.576	31	0	$4.825 \times 10^{-5}$	—
Engine Type: 2H - 3%	18.515	3.495	40	20	—	6.8

\*Phase I

Table 87

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P'_0/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 52.98 in.	0	0	0	0	—	87.2
D = 5.298 in.	2.65	.50	3	30	—	65.1
X/D = 10	5.30	1.00	6	54	—	62.4
O/F = 6.0:1	7.36	1.39	10	5	—	56.0
$P_{\text{ambient}} = 55$ Microns	9.25	1.75	12	5	—	54.6
$P_{\text{combustion}} = 532.6$ psia	17.50	3.30	21	0	—	34.4
Engine Type: Equivalent	21.23	4.00	24	0	—	20.3
	23.92	4.50	25	6	—	14.0

Table 88

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 52.98 in.	0	0	0	0	—	64.1
D = 5.298 in.	2.65	.50	3	30	—	50.8
X/D = 10	5.30	1.00	6	54	—	54.5
O/F = 6.0:1	7.36	1.39	10	5	—	60.8
P <sub>ambient</sub> = 5.5 Microns	9.25	1.75	12	5	—	58.7
P <sub>combustion</sub> = 566.5 psia	17.50	3.30	21	0	—	37.6
Engine Type: Equivalent	21.23	4.00	24	0	—	21.1
	23.92	4.50	25	6	—	12.5

Table 89

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P'_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 52.93 in.	0	0	0	0	—	68.3
D = 5.298 in.	17.500	3.30	21	0	—	36.0
X/D = 10	21.125	3.99	23	48	—	Out
O/F = 6.0:1	23.435	4.40	25	6	—	18.1
$P_{\text{ambient}} = 5.5$ Microns	26.375	4.98	27	30	—	12.0
$P_{\text{combustion}} = 601.7$ psia	29.125	5.50	28	58	—	9.0
Engine Type: Equivalent	31.562	5.96	31	36	—	4.5
	35.750	6.76	35	0	—	4.0

Table 90

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 52.98 in.	0	0	0	0	—	40.3
D = 5.298 in.	2.65	.50	2	0	—	40.7
X/D = 10	5.27	1.00	4	12	—	40.0
O/F = 6.0:1	7.95	1.50	6	30	—	29.6
$P_{\text{ambient}} = 4.0$ Microns	10.60	2.00	8	24	—	43.7
$P_{\text{combustion}} = 629.7$ psia	18.54	3.50	15	24	—	38.0
Engine Type: Equivalent	21.20	4.00	16	36	—	31.6
	23.84	4.50	18	36	—	26.5

Table 91

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P'_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 52.98 in. D = 5.298 in. X/D = 10 O/F = 6.0:1 P <sub>ambient</sub> = 5.0 Microns P <sub>combustion</sub> = 718.4 psia Engine Type: 2V - 3%	0	0	0	0	—	77.0
	2.65	.50	3	30	—	67.0
	5.30	1.00	6	54	—	72.0
	7.95	1.50	9	48	—	46.0
	10.29	1.94	13	30	—	41.0
	17.45	3.30	21	0	—	30.0
	21.17	4.00	23	48	—	16.5
	23.27	4.40	25	6	—	16.0

Table 92

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P'_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 52.98 in.	0	0	0	0	—	80.6
D = 5.298 in.	17.500	3.30	21	0	—	30.1
X/D = 10	21.125	3.99	23	48	—	Out
O/F = 6.0:1	23.435	4.40	25	6	—	Out
$P_{\text{ambient}} = 5.5$ Microns	26.375	4.98	27	30	—	Out
$P_{\text{combustion}} = 684.6$ psia	29.125	5.50	28	58	—	Out
Engine Type: 2V - 3%	31.562	5.96	31	36	—	Out
	35.750	6.76	35	0	—	Out

Table 93

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\frac{\theta}{(\text{deg})}$ (min.)		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
X = 52.98 in.	0	0	0	0	—	Out
D = 5.298 in.	2.65	.50	3	30	—	73.0
X/D = 10	5.30	1.00	6	54	—	72.3
O/F = 6.0:1	7.36	1.39	10	5	—	48.2
$P_{\text{ambient}} = 5.2$ Microns	9.25	1.75	12	5	—	52.9
$P_{\text{combustion}} = 726.2$ psia	17.50	3.30	21	0	—	34.1
Engine Type: 2H - 3%	21.23	4.00	24	0	—	25.8
	23.92	4.50	25	6	—	20.2

Table 94

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P'_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 52.98 in.	0	0	0	0	—	67.6
D = 5.298 in.	17.500	3.30	21	0	—	38.4
X/D = 10	21.125	3.99	23	48	—	Out
O/F = 6.0:1	23.435	4.40	25	6	—	Out
$P_{\text{ambient}} = 3.0$ Microns	26.375	4.98	27	30	—	Out
$P_{\text{combustion}} = 709.3$ psia	29.125	5.50	28	58	—	Out
Engine Type: 2H - 3%	31.562	5.96	31	36	—	Out
	35.750	6.76	35	0	—	Out

Table 95\*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	q (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 63.58 in.	0	0	0	0	—	51.3
D = 5.298 in.	2.7	.5	2	44	$1.66 \times 10^{-4}$	—
X/D = 12	6.3	1.2	6	33	$1.11 \times 10^{-4}$	—
O/F = 6.0:1	8.5	1.6	9	10	$1.45 \times 10^{-4}$	—
$P_{\text{ambient}} = 2.0$ Microns	14.5	2.7	14	20	$1.14 \times 10^{-4}$	—
$P_{\text{combustion}} = 577.2$ psia	17.5	3.3	18	3	$9.88 \times 10^{-5}$	—
Engine Type: Equivalent	21.2	4.0	21	4	$4.30 \times 10^{-5}$	—
	23.8	4.5	22	56	$2.13 \times 10^{-6}$	—

\* Phase I

Table 96 \*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 63.58 in.	0	0	0	0	—	60.3
D = 5.298 in.	2.7	.5	2	44	$1.99 \times 10^{-4}$	—
X/D = 12	6.3	1.2	6	33	$1.31 \times 10^{-4}$	—
O/F = 6.0:1	8.5	1.6	9	10	$1.64 \times 10^{-4}$	—
$P_{ambient} = 2.0$ Microns	14.5	2.7	14	20	$1.41 \times 10^{-4}$	—
$P_{combustion} = 620.6$ psia	17.5	3.3	18	3	$1.12 \times 10^{-4}$	—
Engine Type: 2H - 3 %	21.2	4.0	21	4	$6.29 \times 10^{-5}$	—
	23.8	4.5	22	56	$2.02 \times 10^{-6}$	—

\* Phase I

Table 97\*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	---	0 <sub>gt</sub>
D = 5.298 in.	2.55	.481	2	6	$1.077 \times 10^{-4}$	---
X/D = 15	5.20	.981	4	18	$1.096 \times 10^{-4}$	---
O/F = 6.0:1	7.90	1.491	6	30	$9.806 \times 10^{-5}$	---
P <sub>ambient</sub> = 6.8 microns	10.50	1.982	8	24	$1.064 \times 10^{-4}$	---
P <sub>combustion</sub> = 608.8 psia	15.89	2.999	13	12	$7.38 \times 10^{-5}$	---
Engine Type: Equivalent	18.45	3.482	15	24	$7.85 \times 10^{-5}$	---
	21.30	4.001	16	36	$7.13 \times 10^{-5}$	---
*Phase I	23.79	4.490	18	36	---	29.1

Table 98\*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	—	41.9
D = 5.298 in.	2.55	.481	2	6	$1.100 \times 10^{-4}$	—
X/D = 15	5.20	.981	4	18	$1.161 \times 10^{-4}$	—
O/F = 6.0:1	7.90	1.491	6	30	$1.063 \times 10^{-4}$	—
$P_{ambient} = 6.0$ Microns	10.50	1.982	8	24	$1.066 \times 10^{-4}$	—
$P_{combustion} = 542.6$ psia	15.89	2.999	13	12	$9.113 \times 10^{-5}$	—
Engine Type: Equivalent	18.45	3.482	15	24	$8.403 \times 10^{-5}$	—
	21.30	4.001	16	36	$7.625 \times 10^{-5}$	—
	23.79	4.490	18	36	—	29.8

\*Phase I

Table 99

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.4 in. D = 5.298 in. X/D = 15 O/F = 6.0:1 P <sub>ambient</sub> = 4.0 microns P <sub>combustion</sub> = 629.7 psia Engine Type: Equivalent	0	0	0	0	—	40.3
	.5	2.65	2	0	—	40.7
	1.0	5.30	4	12	—	40.0
	1.5	7.95	6	30	—	29.6
	2.0	10.60	8	24	—	43.7
	3.5	18.54	15	24	—	38.0
	4.0	21.20	16	36	—	31.6
	4.5	23.84	18	36	—	26.5

Table 100\*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_i/P_c$	q (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.4 in.	0	0	0	0	—	35.2
D = 5.198 in.	2.00	.5	2	1	—	38.8
X/D = 15	5.00	1.0	4	13	—	46.9
O/F = 6.0:1	7.93	1.5	6	24	—	44.1
P <sub>ambient</sub> = 1.0 Microns	10.56	2.0	8	34	—	33.8
P <sub>combustion</sub> = 557.3 psia	18.51	3.5	15	19	—	36.0
Engine Type: Equivalent	21.18	4.0	16	50	—	31.0
	23.80	4.5	18	42	—	24.8
	26.43	5.0	20	58	—	23.9
*Phase I	29.10	5.5	22	19	—	13.6

Table 101\*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.4 in.	0	0	0	0	—	37.0
D = 5.298 in.	7.93	1.50	6	24	—	40.2
X/D = 15	10.56	2.00	8	34	—	34.2
O/F = 6.0:1	18.51	3.50	15	19	—	33.8
$P_{ambient} = 1.0$ Microns	21.18	4.00	16	50	—	31.3
$P_{combustion} = 566.2$ psia	23.80	4.50	18	42	—	26.0
Engine Type: Equivalent	26.43	5.00	20	58	—	24.6
	29.10	5.50	22	19	—	15.2
	31.75	6.00	24	0	—	17.1
*Phase I	35.75	6.76	25	35	—	11.0

Table 102

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P'_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	—	34.58
D = 0.298 in.	18.54	3.50	15	24	—	25.50
X/D = 15	21.20	4.00	16	36	—	30.31
O/F = 6.0:1	23.84	4.50	18	36	—	25.18
$P_{ambient} = 2.5$ Microns	26.45	5.00	20	54	—	21.09
$P_{combustion} = 610.7$ psia	29.10	5.50	22	24	—	10.5
Engine Type: Equivalent	31.75	6.00	24	24	—	9.74
	35.75	6.76	25	30	—	9.95

Table 103\*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	—	52.8
D = 5.298 in.	2.55	.481	2	6	$1.172 \times 10^{-4}$	—
X/D = 15	5.20	.981	4	18	$1.399 \times 10^{-4}$	—
O/F = 6.0:1	7.90	1.491	6	30	$1.223 \times 10^{-4}$	—
$P_{\text{ambient}} = 5.8$ Microns	10.50	1.982	8	24	$1.202 \times 10^{-4}$	—
$P_{\text{combustion}} = 534.4$ psia	15.89	2.999	13	12	$6.970 \times 10^{-5}$	—
Engine Type: 2V - 3%	18.45	3.482	15	24	$4.631 \times 10^{-5}$	—
	21.30	4.001	16	36	$4.339 \times 10^{-5}$	—
	23.79	4.490	18	36	—	16.2

\*Phase I

Table 104

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P'_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	—	48.78
D = 5.298 in.	2.65	.5	2	0	—	43.23
X/D = 15	5.30	1.0	4	12	—	49.08
O/F = 6.0:1	18.54	3.5	15	24	—	24.03
$P_{ambient} = 4.5$ Microns	21.20	4.0	16	36	—	19.62
$P_{combustion} = 703.4$ psia	23.84	4.5	18	36	—	15.27
Engine Type: 2V - 3%	26.45	5.0	20	54	—	15.25
	29.10	5.5	22	24	—	13.34

Table 105

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in	0	0	0	0	—	38.00
D = 5.298 in.	18.54	3.50	15	24	—	25.51
X/D = 15	21.20	4.00	16	36	—	20.00
O/F = 6.0:1	23.84	4.50	18	36	—	17.21
P <sub>ambient</sub> = 4.2 Microns	26.45	5.00	20	54	—	15.50
P <sub>combustion</sub> = 715.8 psia	29.10	5.50	22	24	—	18.01
Engine Type: 2V - 3%	31.75	6.00	24	24	—	5.49
	35.75	6.76	25	30	—	2.91

Table 106

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	—	77.0
D = 5.298 in.	2.65	.5	2	0	—	55.5
X/D = 15	5.30	1.0	4	12	—	60.0
O/F = 6.0:1	18.54	3.5	15	24	—	38.2
$P_{ambient} = 5.0$ Microns	21.20	4.0	16	36	—	34.0
$P_{combustion} = 718.4$ psia	23.84	4.5	18	36	—	25.0
Engine Type: 2V - 3%	26.45	5.0	20	54	—	13.7
	29.10	5.5	22	24	—	13.3

Table 107

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	—	80.0
D = 5.298 in.	17.500	3.30	21	0	—	30.1
X/D = 15	21.125	3.99	23	48	—	Out
O/F = 6.0:1	23.437	4.40	25	6	—	Out
$P_{ambient} = 5.5$ Microns	26.375	4.98	27	30	—	Out
$P_{combustion} = 684.6$ psia	29.125	5.50	28	58	—	Out
Engine Type: 2V - 3%	31.562	5.96	31	36	—	Out
	35.75	6.76	35	0	—	Out

Table 108\*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	—	101.8
D = 5.298 in.	2.55	.481	2	6	$1.147 \times 10^{-4}$	—
X/D = 15	5.20	.981	4	18	$1.468 \times 10^{-4}$	—
O/F = 6.0:1	7.90	1.491	6	30	$1.352 \times 10^{-4}$	—
$P_{\text{ambient}} = 5.0$ Microns	10.50	1.982	8	24	$1.298 \times 10^{-4}$	—
$P_{\text{combustion}} = 567.6$ psia	15.89	2.999	13	12	$1.129 \times 10^{-4}$	—
Engine Type: 2H - 3%	18.45	3.482	15	24	$1.054 \times 10^{-4}$	—
	21.30	4.001	16	36	$9.088 \times 10^{-5}$	—
	23.79	4.490	18	36	—	27.3

\*Phase I

Table 109

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P'_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	—	Out
D = 5.298 in.	2.65	.5	2	0	—	50.7
X/D = 15	5.27	1.0	4	12	—	Out
O/F = 6.0:1	18.54	3.5	15	24	—	38.0
$P_{ambient} = 3.5$ Microns	21.20	4.0	16	36	—	39.0
$P_{combustion} = 735.7$ psia	23.84	4.5	18	36	—	37.0
Engine Type: 2H - 3%	26.45	5.0	20	54	—	30.0
	29.10	5.5	22	24	—	27.8

Table 110

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	0		$P'_0/P_c$	q (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	—	48.00
D = 5.298 in.	18.54	3.50	15	24	—	39.50
X/D = 15	21.20	4.00	16	24	—	38.50
O/F = 6.0:1	23.84	4.50	18	24	—	31.50
$P_{\text{ambient}} = 4.5$ Microns	26.45	5.00	20	54	—	29.00
$P_{\text{combustion}} = 719.9$	29.10	5.50	22	24	—	25.00
Engine Type: 2H - 3%	31.75	6.00	24	24	—	29.28
	35.75	6.76	25	30	—	23.40

Table III\*

IBFF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	q (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	—	41.4
D = 5.298 in.	2.7	.5	2	1	$5.99 \times 10^{-5}$	—
X/D = 15	5.3	1.0	4	45	$4.57 \times 10^{-5}$	—
O/F = 6.0:1	7.9	1.5	6	24	$1.16 \times 10^{-4}$	—
P <sub>ambient</sub> = 1.0 Microns	10.6	2.0	8	23	$1.07 \times 10^{-4}$	—
P <sub>combustion</sub> = 653.3 psia	18.5	3.5	15	44	$8.19 \times 10^{-5}$	—
Engine Type: 2H - 3%	21.2	4.0	16	44	$4.68 \times 10^{-5}$	—
	23.8	4.5	19	9	$2.25 \times 10^{-6}$	—

\*Phase I

Table 112\*

IBBF 3% General Dynamics Booster/Separation Impingement Test (Plume Definition)						
Facility Parameters	R (in.)	R/D	$\theta$		$P_o/P_c$	$q$ (Btu/ft <sup>2</sup> -sec)
			(deg)	(min.)		
X = 79.5 in.	0	0	0	0	—	37.7
D = 5.298 in.	18.50	3.5	15	32	$7.29 \times 10^{-5}$	—
X/D = 15	21.20	4.0	16	53	$4.91 \times 10^{-5}$	—
O/F = 6.0:1	23.80	4.5	19	0	$2.09 \times 10^{-6}$	—
$P_{\text{ambient}} = 2.0$ Microns	26.40	5.0	20	50	$4.98 \times 10^{-5}$	—
$P_{\text{combustion}} = 646.6$ psia	29.10	5.5	23	34	$1.58 \times 10^{-5}$	—
Engine Type: 2H- 3%	31.75	6.0	24	0	$3.29 \times 10^{-5}$	—
	35.75	6.76	25	35	$1.83 \times 10^{-5}$	—

\*Phase I

Table 113

## BOOSTER IMPINGEMENT TEST CONDITIONS

Table No.	Test Position	Engine Config.	Run No.	Symbol	X (in.)	Y (in.)	$\alpha$ (deg.)	P <sub>c</sub> (psia)	P <sub>∞</sub> (μHg)
114	2	1	10/0	□	-3.297	4.644	0	671.8	3.0
115	2	1	11/0	□			0	633.1	2.5
116	2	1	13/0	■			0	644.1	2.0
117	2	1	59/0	□			0	563.6	5.4
118	2	1	60/0	□	-3.297	4.644	0	577.5	5.0
119	2	2H	14/1	●			0	669.4	3.0
120	2	2H	15/0	○			0	611.3	2.0
121	2	2H	17/1	○	-3.297	4.644	0	670.0	2.0
122	4	1	45/0	■	-18.390	6.966	0	707.2	2.0
123	5	1	40/0	■	-6.780	6.966	0	735.7	2.0
124	5	1	41/0	□			0	681.4	1.5
125	5	1	42/0	□			0	705.5	9.0
126	5	1	87/0	□			0	580.9	3.8
127	5	1	88/0	■			0	592.7	4.8
128	5	2H	18/1	○			0	671.8	3.0
129	5	2H	19/0	○			0	679.7	6.0
130	5	2H	20/0	○	-6.780	6.966	0	612.4	6.0
131	8	2H	31/1	◐	-6.780	6.966	5	679.7	2.5
132	8	2H	32/0	◐	-6.780	6.966	5	669.2	2.0
133	8	2H	33/0	◐	-6.780	6.966	5	692.1	2.0

Table 113 (Continued)

Table No.	Test Position	Engine Config.	Run No.	Symbol	X (in)	Y (in.)	$\alpha$ (deg.)	P <sub>c</sub> (psia)	P <sub>∞</sub> (μHg)
134	11	2H	29/0	◐	-11.424	14.513	4	657.1	4.0
135	11	2H	30/0	◑	-11.424	14.513	4	710.5	4.0
136	14	1	43/1	◒	-11.424	14.513	0	733.5	1.8
137	14	1	44/1	◓	-11.424	14.513	0	514.9	2.0
138	14	2H	21/1	◯	-11.424	14.513	0	709.9	2.0
139	14	2H	22/0	◉	-11.424	14.513	0	632.6	10.0
140	15	1	27/0	◑	.186	14.513	0	731.6	3.0
141	15	1	27/1	◐			0	606.0	1.8
142	15	1	28/0	◒			0	671.5	3.3
143	15	1	28/1	◓			0	546.4	1.4
144	15	1	96/0	◑			0	515.0	5.5
145	15	1	96/1	◒	.186	14.513	0	626.1	4.0
146	15*	1	55/0	◑	.186	14.938	0	626.3	5.5
147	15*	1	56/1	◒	.186	14.938	0	612.5	4.0
148	15*	2H	80/1	◯	.186	14.938	0	677.0	5.0
149	15*	2H	81/1	◉	.186	14.938	0	749.4	3.0
150	15	2H	25/0	◯	.186	14.513	0	708.7	3.0
151	15	2H	26/0	◉	.186	14.513	0	697.6	3.0
152	17	1	79/0	◒	-6.780	23.220	0	589.5	3.0
153	17	1	79/1	◓			0	586.9	3.0
154	17	2H	23/1	◯			0	597.4	3.0
155	17	2H	24/0	◑			0	560.0	4.0
156	17	2H	78/0	◉			0	741.4	4.0
157	17	2H	78/1	◐			0	703.7	4.0
158	17	2V	63/0	◈			0	698.6	5.0
159	17	2V	64/0	◈	-6.780	23.220	0	720.6	5.0

\* See each table for explanation

Table 113 (Concluded)

Table No.	Test Position	Engine Config.	Run No.	Symbol	X (in.)	X (in.)	$\alpha$ (deg.)	P <sub>c</sub> (psia)	P <sub>∞</sub> (μHg)
160	29	1	95/0	□	-6.780	23.220	5	596.8	5.5
161	29	1	95/1	□			5	607.9	5.0
162	29	2H	34/0	□			5	679.2	2.0
163	29	2H	35/1	□			5	626.6	2.0
164	29	2H	94/0	□			5	712.4	5.0
165	29	2H	94/1	□			5	686.0	5.0
166	29	2V	93/0	□			5	716.0	5.5
167	29	2V	93/1	□	-6.780	23.220	5	710.4	4.4
168	30	1	84/0	□	-1.180	23.220	0	576.7	3.0
169	30	1	84/1	□			0	636.9	4.5
170	30	1	37/0	□			0	573.3	2.0
171	30	2H	36/0	○			0	685.2	2.0
172	30	2H	97/0	●			0	800.4	4.0
173	30	2H	97/1	●			0	625.7	5.5
174	30	2V	83/0	◇			0	700.4	5.5
175	30	2V	83/1	◇	-1.180	23.220	0	642.3	3.0
176	31	1	39/0	□	-8.424	14.513	0	487.5	2.0
177	31	1	86/0	□			0	539.9	5.2
178	31	1	86/1	□			0	570.0	3.5
179	31	2H	38/0	○	-8.424	14.513	0	682.6	2.0

Table 114  
Test Pt. 2, Run 10/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> -sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> -sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> -sec
1	.0002	—	60	1.7979	—	None	None	None
2	Out	—	61	—	Out			
3	.0023	—	66	—	Out			
4	.0033	—	67	1.2806	—			
10	Out	—	72	—	355.89			
11	.0002	—	73	—	Out			
12	.0042	—	77	.2664	—			
			78	—	209.77			
			79	.0890	—			
			85	—	20.32			
			87	.1136	—			
			88	.0141	—			
			89	—	Out			
			95	—	8.55			
			96	.0454	—			
			97	—	92.04			
			98	Out	—			
			99	—	2.54			

Table 115  
Test Pt. 2, Run 11/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec
5	.0022	—	None	None	None	None	None	None
9	.0347	—						
14	—	9.64						
15	—	3.74						
16	—	4.06						
17	—	.35						
19	.0655	—						
20	.0569	—						
21	.0208	—						
22	.0037	—						
24	—	10.45						
25	.0725	—						
26	.0595	—						
27	.0328	—						
28	.0003	—						
29	.0003	—						
30	—	9.02						
33	.0538	—						
34	.0595	—						
35	.0073	—						
36	.0075	—						
39	—	6.83						
40	—	1.46						
53	—	6.59						
62	—	6.12						

Table 116  
Test Pt. 2, Run 13/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec
6	—	.762	100	—	1.51	None	None	None
7	—	.252						
14	—	8.69						
15	—	5.45						
16	—	1.78						
18	—	.194						
24	—	9.43						
30	—	7.78						
47	.0477	—						
48	.0384	—						
49	.0198	—						
50	.0055	—						
53	—	6.14						
55	.0308	—						
56	.0171	—						
57	.0061	—						
68	.0573	—						
69	.0180	—						
70	Out	—						
80	.0368	—						
81	.0006	—						
82	.0052	—						
90	.0090	—						
91	.0247	—						

Table 117  
Test Pt.2, Run 59/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
6	—	1.20	60	1.15356	—	None	None	None
9	.03753	—	67	.92717	—			
14	—	Out	77	.40927	—			
15	—	4.31	78	—	142.00			
16	—	7.55	79	.08183	—			
17	—	7.54	85	—	11.51			
19	.07880	—	87	.14030	—			
20	.04964	—	88	.03694	—			
21	.00726	—	89	—	63.89			
22	.00243	—	95	—	3.23			
24	—	19.79	96	.03997	—			
25	.07256	—	97	—	Out			
26	.04842	—	100	—	.68			
27	.06300	—						
30	—	15.82						
33	.05698	—						
34	Out	—						
35	Out	—						
36	.01703	—						
39	—	12.08						
47	Out	—						
48	.03397	—						
49	.04551	—						
50	.02027	—						

Table 117 (Continued)  
 Test Pt.2, Run 59/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec
53	—	11.87				None	None	None
55	.04990	—						
56	Out	—						
57	.01481	—						
62	—	12.88						
68	.01691	—						
69	.04428	—						
70	Out	—						
80	.00320	—						
82	.03009	—						
90	.00440	—						
91	.02608	—						

Table 118  
Test Pt. 2, Run 60/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
6	—	1.23	60	.99438	—	None	None	None
9	.03425	—	67	1.01662	—			
14	—	1.54	77	.43389	—			
15	—	5.60	78	—	142.58			
16	—	7.46	79	.08488	—			
17	—	7.46	85	—	10.30			
19	.07477	—	87	.15794	—			
20	.04786	—	88	.03553	—			
21	Out	—	89	—	74.55			
22	.00220	—	95	—	44.53			
24	—	16.73	96	.04160	—			
25	.07058	—	97	—	30.26			
26	.05003	—	100	—	1.57			
27	.05865	—						
30	—	14.80						
33	.06052	—						
34	.04546	—						
35	Out	—						
36	.01805	—						
39	—	72.97						
47	.00723	—						
48	.03155	—						
49	.04378	—						
50	.02090	—						

Table 118 (Continued)  
Test Pt. 2, Run 60/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
53	—	12.16				None	None	None
55	Out	—						
56	Out	—						
57	Out	—						
62	—	12.23						
68	.01614	—						
69	.03397	—						
70	Out	—						
80	Out	—						
82	.02436	—						
90	.00579	—						
91	Out	—						

Table 119  
Test Pt. 2, Run 14/1, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
1	.0001	—	60	1.1286	—	None	None	None
2	.0000	—	61	—	Out			
3	.0010	—	66	—	Out			
4	.0016	—	67	1.4920	—			
10	Out	—	72	—	Out			
11	.0002	—	73	—	Out			
12	.0016	—	77	.4085	—			
			78	—	Out			
			79	.1133	—			
			85	—	11.20			
			87	.1088	—			
			88	.0140	—			
			89	—	60.06			
			95	—	4.81			
			96	.0426	—			
			97	—	27.33			
			98	Out	—			
			99	—	1.54			

Table 120  
Test Pt. 2, Run 15/0, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
5	.0000	—	None	None	None	None	None	None
9	.0276	—						
14	—	6.65						
15	—	1.54						
16	—	1.21						
17	—	Out						
19	.0643	—						
20	.0250	—						
21	.0164	—						
22	.0037	—						
24	—	7.96						
25	.0852	—						
26	.0358	—						
27	.0256	—						
28	.0001	—						
29	.0004	—						
30	—	7.76						
33	.0745	—						
34	.0365	—						
35	.0064	—						
36	.0083	—						
39	—	6.67						
40	—	1.30						
53	—	5.16						
62	—	6.18						

Table 121  
Test Pt. 2, Run 17/1, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec
6	—	2.42	100	—	1.43	None	None	None
7	—	.301						
14	—	6.44						
15	—	1.91						
16	—	1.26						
18	—	.087						
24	—	9.03						
30	—	9.01						
47	.0791	—						
48	.0392	—						
49	.0255	—						
50	Out	—						
53	—	5.63						
55	.0457	—						
56	.0205	—						
57	.0102	—						
68	.1150	—						
69	.0230	—						
70	.0065	—						
80	.0539	—						
81	Out	—						
82	.0083	—						
90	.0113	—						
91	.0451	—						

Table 122  
Test Pt.4, Run 45/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	$P_x$ psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	$P_x$ psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	$P_x$ psia	$\dot{q}$ Btu/ft <sup>2</sup> sec
68	.0137	—	66	—	Out	None	None	None
69	.0100	—	67	2.085	—			
80	.0207	—	72	—	Out			
81	.0320	—	73	—	Out			
82	.0063	—	77	5.198	—			
90	Out	—	78	—	Out			
91	.0253	—	79	.5024	—			
92	Out	—	85	—	1.71			
93	.0002	—	87	.5518	—			
			88	.3099	—			
			89	—	Out			
			95	—	.752			
			96	.0328	—			
			97	—	.530			
			99	—	.258			
			100	—	.170			

Table 123  
Test Pt. 5, Run 40/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	$P_x$ psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	$P_x$ psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	$P_x$ psia	$\dot{q}$ Btu/ft <sup>2</sup> sec
68	.0279	—	60	.2917	—	None	None	None
69	.0193	—	61	—	Out			
70	.0061	—	66	—	Out			
80	.0377	—	67	.9326	—			
81	.0104	—	72	—	Out			
82	.0085	—	73	—	Out			
			77	1.3436	—			
			78	—	Out			
			79	.1766	—			
			85	—	17.13			
			87	.2994	—			
			88	.0687	—			
			89	—	Out			
			95	—	6.53			
			96	.0995	—			
			97	—	6.30			
			98	.0005	—			
			99	—	2.04			
			100	—	2.11			

Table 124  
Test Pt. 5, Run 41/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
15	—	.373	60	.3145	—	None	None	None
16	—	.401	67	.9572	—			
18	—	.557	77	1.4656	—			
25	.0203	—	79	.1476	—			
33	.0297	—	87	.3302	—			
34	.0011	—	96	.1064	—			
39	—	5.71						
40	—	.949						
47	.0417	—						
48	.0472	—						
49	.0006	—						
55	.0448	—						
62	—	9.16						
63	—	1.54						
64	—	.234						
68	.0291	—						
74	—	7.74						
75	—	1.07						
80	.0416	—						

Table 175  
Test Pt. 5, Run 42/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
14	—	.417	None	None	None	32	—	.341
24	—	1.31				38	—	.285
25	.0226	—				41	—	.74
26	.0078	—				42	—	.174
30	—	4.84				43	—	.215
33	.0262	—				44	—	.409
34	.0230	—						
35	.0189	—						
36	.0021	—						
37	.0012	—						
47	.0381	—						
48	.0423	—						
49	.0009	—						
50	.0032	—						
51	Out	—						
53	—	6.71						
55	.0416	—						
56	.0150	—						
57	.0042	—						

Table 126  
Test Pt. 5, Run 87/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
19	.00483	—	60	.18743	—	None	None	None
20	.00611	—	67	1.05928	—			
21	.00269	—	77	.90472	—			
25	.01719	—	79	.16038	—			
26	Out	—	85	—	15.95			
27	.00515	—	87	.72619	—			
28	.00154	—	88	.09621	—			
29	Out	—	89	—	198.47			
30	—	Out	95	—	4.37			
33	.03204	—	96	.06891	—			
34	.02632	—	97	—	Out			
35	Out	—	99	—	1.96			
36	.00285	—	100	—	.63			
37	.00670	—						
39	—	5.18						
40	—	.67						
47	.05045	—						
48	.02751	—						
50	.00524	—						
51	.00004	—						
53	—	1.03						
55	.02256	—						
56	.01212	—						

Table 126 (Continued)  
Test Pt. 5, Run 87/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	$P_x$ psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	$P_x$ psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	$P_x$ psia	$\dot{q}$ Btu/ft <sup>2</sup> sec
57	Out	—				None	None	None
58	Out	—						
62	—	7.01						
63	—	4.73						
64	—	6.45						
68	.03911	—						
69	.02537	—						
70	.00323	—						
71	Out	—						
74	—	Out						
75	—	Out						
80	.02067	—						
81	Out	—						
82	.00412	—						
83	.00300	—						
90	.02066	—						
91	.04379	—						

Table 127  
Test Pt. 5, Run 88/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec
19	.00475	—	60	.21485	—	None	None	None
20	.00439	—	67	.98535	—			
21	.00353	—	77	.96195	—			
25	.01438	—	79	.17262	—			
26	.00452	—	85	—	15.17			
27	.00367	—	87	.38200	—			
28	.00081	—	88	.09925	—			
29	Out	—	89	—	Out			
30	—	18.00	95	—	4.50			
33	.03215	—	96	.06813	—			
34	.02715	—	97	—	Out			
35	.00605	—	99	—	2.13			
36	.00126	—	100	—	.84			
37	Out	—						
39	—	5.65						
40	—	Out						
47	.04578	—						
48	.02935	—						
50	.00545	—						
51	.00886	—						
53	—	15.07						
55	.02419	—						
56	.01470	—						

Table 127 (Continued)  
Test Pt. 5, Run 88/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
57	.00394	—				None	None	None
58	Out	—						
62	—	8.32						
63	—	Out						
64	—	9.76						
68	.03532	—						
69	.01955	—						
70	Out	—						
71	Out	—						
74	—	20.07						
75	—	10.36						
80	.01906	—						
81	.01220	—						
82	.00471	—						
83	.00384	—						
90	.01837	—						
91	.04721	—						

Table 128  
Test Pt. 5, Run 18/1, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec
68	.0603	—	60	.2420	—	None	None	None
69	Out	—	61	—	Out			
70	.0064	—	66	—	Out			
80	.0358	—	67	.8393	—			
81	.0294	—	72	—	Out			
82	Out	—	73	—	Out			
			77	1.2123	—			
			78	—	Out			
			79	.2685	—			
			85	—	15.95			
			87	.3946	—			
			88	.0280	—			
			89	—	Out			
			95	—	5.67			
			96	.1040	—			
			97	—	33.60			
			98	Out	—			
			99	—	1.68			

Table 129  
Test Pt. 5, Run 19/0, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec
15	—	.33	60	.1497	—	None	None	None
16	—	.228	67	.9160	—			
18	—	.438	77	1.3567	—			
25	.0403	—	79	.1956	—			
33	.0511	—	87	.3653	—			
34	.0376	—	96	.1153	—			
39	—	7.90						
40	—	1.450						
47	.0430	—						
48	.0361	—						
49	Out	—						
55	.0423	—						
62	—	19.59						
63	—	1.71						
64	—	Out						
68	.0579	—						
74	—	.88						
75	—	1.930						
80	.0343	—						

Table 130  
Test Pt. 5, Run 20/0, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec
14	—	.710	None	None	None	32	—	Out
24	—	2.11				38	—	.080
25	.0230	—				41	—	.000
26	.0084	—				42	—	.050
30	—	.460				43	—	.050
33	.0351	—				44	—	.000
34	.0215	—						
35	.0063	—						
36	.0010	—						
37	.0001	—						
47	.0339	—						
48	.0293	—						
49	.0114	—						
50	.0002	—						
51	.0003	—						
53	—	7.08						
55	.0353	—						
56	.0054	—						
57	.0018	—						

Table 131  
Test Pt. 8, Run 31/1, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> Psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> Psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> Psia	q Btu/ft <sup>2</sup> sec
68	.0933	—	60	.5676	—	None	None	None
69	.0296	—	61	—	Out			
70	.0202	—	66	—	Out			
80	.0830	—	67	1.903	—			
81	.0632	—	72	—	Out			
82	.0157	—	73	—	Out			
			77	.3957	—			
			78	—	Out			
			79	.1409	—			
			85	—	12.64			
			87	.1719	—			
			88	.0021	—			
			89	—	Out			
			95	—	6.08			
			96	.0320	—			
			97	—	25.20			
			98	Out	—			
			99	—	1.95			
			100	—	1.80			

Table 132  
Test Pt. 8, Run 32/0, Horizontal Two-Engine Conf.

Engine			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec
15	—	.011	60	.5237	—	None	None	None
16	—	.151	67	1.5410	—			
18	—	.074	77	.2782	—			
25	.0531	—	79	.1203	—			
33	.1040	—	87	.1552	—			
34	.0252	—	96	.0250	—			
39	—	5.43						
40	—	1.34						
47	.1026	—						
48	.0332	—						
49	.0002	—						
55	.0714	—						
62	—	1.44						
63	—	1.79						
64	—	.375						
68	.0746	—						
74	—	11.13						
75	—	1.92						
80	.0788	—						

Table 133  
Test Pt. 8, Run 33/0, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> Psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> Psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> Psia	$\dot{q}$ Btu/ft <sup>2</sup> sec
14	—	.00	None	None	None	32	—	.08
24	—	4.30				38	—	.08
25	.0571	—				41	—	.01
26	.0137	—				42	—	.08
30	—	9.05				43	—	.08
33	.1108	—				44	—	.18
34	.0258	—						
35	.0163	—						
36	Out	—						
37	.0008	—						
47	.0974	—						
48	.0345	—						
49	Out	—						
50	.0020	—						
51	Out	—						
53	—	8.47						
55	.0831	—						
56	.0339	—						
57	.0093	—						

Table 134  
Test Pt. 11, Run 29/0, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec
68	Out	—	60	Out	—	None	None	None
80	.0060	—	61	—	11.35			
81	Out	—	66	—	25.43			
82	.0023	—	67	.0645	—			
90	.0041	—	72	—	38.22			
91	.0118	—	73	—	Out			
92	.0063	—	77	.3050	—			
93	.0002	—	78	—	Out			
			79	.0922	—			
			85	—	11.30			
			87	.8743	—			
			88	.0008	—			
			89	—	Out			
			95	—	5.12			
			96	Out	—			
			97	—	Out			
			99	—	1.32			

Table 135  
Test Pt. 11, Run 30/0, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec
53	—	—	78	—	Out	None	None	None
56	.0005	—	89	—	Out			
57	.0003	—	97	—	Out			
58	.0002	—	100	—	3.084			
62	—	5.12						
63	—	.467						
64	—	.422						
68	.0107	—						
69	.0002	—						
0	Out	—						
71	.0001	—						
74	—	.652						
75	—	.693						
80	.0076	—						
81	.0160	—						
82	.0029	—						
83	Out	—						
90	.0051	—						
91	Out	—						
92	Out	—						
93	.0003	—						

Table 136  
Test Pt. 14, Run 43/1, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
68	.0025	—	60	Out	—	None	None	None
80	.0021	—	61	—	4.43			
81	.0073	—	66	—	25.26			
82	.0018	—	67	.0372	—			
90	.0023	—	72	—	33.30			
91	.0042	—	73	—	—			
92	.0038	—	77	.2001	—			
93	.0001	—	78	—	Out			
			79	.0339	—			
			85	—	7.35			
			87	.8280	—			
			88	.0223	—			
			89	—	Out			
			95	—	2.60			
			96	1.7283	—			
			97	—	Out			
			99	—	1.03			

Table 137  
Test Pt. 14, Run 44/1, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
52	—	.333	78	—	Out	None	None	None
56	.0002	—	89	—	Out			
57	.0003	—	97	—	Out			
58	.0001	—	100	—	.894			
62	—	.558						
63	—	.171						
64	—	.041						
68	Out	—						
69	.0012	—						
70	.0006	—						
71	Out	—						
74	—	.485						
75	—	.285						
80	.0014	—						
81	.0021	—						
82	.0012	—						
83	.0001	—						
90	.0016	—						
91	.0028	—						
92	.0021	—						
93	.0001	—						

Table 138  
Test Pt. 14, Run 21/1, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
68	Out	—	60	Out	—	None	None	None
80	.0043	—	61	—	8.22			
81	.0001	—	66	—	14.27			
82	Out	—	67	.0398	—			
90	Out	—	72	—	25.52			
91	Out	—	73	—	Out			
92	Out	—	77	.0140	—			
93	Out	—	78	—	Out			
			79	.0437	—			
			85	—	6.76			
			87	Out	—			
			88	.0221	—			
			89	—	Out			
			95	—	3.09			
			96	1.4712	—			
			97	—	Out			
			99	—	.985			

Table 139  
Test Pt. 14, Run 22/0, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
53	—	1.53	78	—	Out	None	None	None
56	Out	—	89	—	Out			
57	Out	—	97	—	Out			
58	Out	—	100	—	.00			
62	—	1.19						
63	—	Out						
64	—	.00						
68	.0061	—						
69	.0039	—						
70	Out	—						
71	.0000	—						
74	—	Out						
75	—	.00						
80	.0051	—						
81	.0059	—						
82	.0002	—						
83	.0000	—						
90	.0024	—						
91	.0004	—						
92	.0023	—						
93	.0001	—						

Table 140  
Test Pt. 15, Run 27/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec
36	.0018	—	60	.0343	—	None	None	None
50	.0018	—	61	—	23.41			
57	.0026	—	66	—	43.91			
70	.0002	—	67	.1030	—			
82	.0030	—	72	—	Out			
83	.0004	—	73	—	Out			
93	Out.	—	77	.2070	—			
			78	—	Out			
			79	.0484	—			
			85	—	8.57			
			87	.4633	—			
			88	.0235	—			
			89	—	Out			
			95	—	3.79			
			96	.4054	—			
			97	—	Out			
			98	Out	—			
			99	—	1.21			

Table 141  
Test Pt. 15, Run 27/1, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
36	Out	—	60	.0590	—	None	None	None
50	Out	—	61	—	53.31			
57	.0024	—	66	—	144.73			
70	.0030	—	67	.1220	—			
82	.0024	—	72	—	Out			
83	Out	—	73	—	Out			
93	.0010	—	77	.4120	—			
			78	—	362.84			
			79	.0685	—			
			85	—	13.01			
			87	.3293	—			
			88	.0316	—			
			89	—	Out			
			95	—	5.18			
			96	.3132	—			
			97	—	Out			
			98	.0003	—			
			99	—	1.43			

Table 142  
Test Pt. 15, Run 28/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
33	.0061	—	73	—	Out	None	None	None
34	.0075	—	89	—	Out			
35	.0063	—	97	—	Out			
47	.0072	—	100	—	1.578			
48	.0050	—						
49	.0007	—						
53	—	.231						
55	.0047	—						
56	.0018	—						
62	—	.662						
63	—	.260						
64	—	.732						
68	.0087	—						
69	.0063	—						
74	—	1.32						
75	—	.889						
80	.0087	—						
81	.0089	—						
90	.0058	—						
91	Out	—						
92	.0051	—						

Table 143  
Test Pt. 15, Run 28/1, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	$P_x$ psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	$P_x$ psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	$P_x$ psia	$\dot{q}$ Btu/ft <sup>2</sup> sec
33	.0026	—	73	—	Out	None	None	None
34	.0014	—	89	—	Out			
35	.0016	—	97	—	Out			
47	.0077	—	100	—	1.52			
48	.0048	—						
49	.0036	—						
53	—	2.01						
55	.0089	—						
56	.0045	—						
62	—	2.18						
63	—	Out						
64	—	.166						
68	.0060	—						
69	.0040	—						
74	—	1.25						
75	—	.750						
80	Out	—						
81	.0052	—						
90	.0039	—						
91	Out	—						
92	.0026	—						

Table 144  
Test Pt. 15, Run 96/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec
19	.00065	—	60	.02646	—	None	None	None
25	Out	—	61	—	Out			
26	.00143	—	67	.08755	—			
27	Out	—	73	—	Out			
28	Out	—	77	.19870	—			
29	Out	—	79	.03885	—			
33	.00292	—	85	—	Out			
34	.00205	—	87	.54444	—			
35	.00138	—	88	.02218	—			
36	Out	—	95	—	Out			
37	Out	—	96	.45881	—			
47	Out	—	99	—	Out			
48	.00120	—	100	—	Out			
49	.00211	—						
50	.00101	—						
51	Out	—						
55	.00817	—						
56	Out	—						
57	Out	—						
58	Out	—						
62	—	Out						
63	—	Out						
64	—	Out						

Table 144 (Continued)  
Test Pt. 15, Run 96/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec
68	.00678	—				None	None	None
69	Out	—						
70	Out	—						
71	Out	—						
74	—	Out						
75	—	Out						
80	.00367	—						
81	.00438	—						
82	.00645	—						
90	.00357	—						
91	.00468	—						
92	.00138	—						

Table 145  
Test Pt. 15, Run 96/1, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec
19	.00114	—	60	.03903	—	None	None	None
25	Out	—	61	—	21.6			
26	.00250	—	67	.08755	—			
27	.00271	—	73	—	2.42			
28	Out	—	77	.18982	—			
29	.00022	—	79	.04277	—			
30	—	.48	85	—	7.97			
33	.00384	—	87	.50076	—			
34	.00307	—	88	.02401	—			
35	.00217	—	95	—	3.47			
36	.00204	—	96	.35613	—			
37	Out	—	99	—	1.09			
39	—	.84	100	—	1.34			
47	.00424	—						
48	.00289	—						
49	.00264	—						
50	Out	—						
51	.00033	—						
55	.00723	—						
56	Out	—						
57	.00206	—						
58	Out	—						
62	—	2.46						
63	—	.70						

Table 145 (Continued)  
Test Pt. 15, Run 96/1, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
64	—	.13				None	None	None
68	.00770	—						
69	.00457	—						
70	Out	—						
71	Out	—						
74	—	.32						
75	—	Out						
80	.00262	—						
81	Out	—						
82	Out	—						
90	.00307	—						
91	.00498	—						
92	.00092	—						

Table 146  
Test Pt. 15\*, Run 55/1, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec
39	—	1.52	61	—	27.50	None	None	None
40	—	.56	66	—	58.50			
53	—	2.58	72	—	103.90			
62	—	3.05	73	—	161.00			
63	—	1.02	85	—	10.50			
64	—	.43	89	—	220.00			
74	—	2.35	95	—	4.90			
75	—	1.35	97	—	180.30			
			99	—	.66			
			100	—	1.82			

\* Y coordinate location off by + 0.445 inch

Table 147  
Test Pt. 15\*, Run 56/1, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> -sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> -sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> -sec
40	—	.25	61	—	23.90	No.e	None	None
62	—	2.29	66	—	42.54			
63	—	.75	85	—	4.43			
74	—	1.39	100	—	1.48			

\* Y coordinate location off by + 0.445 inch

Table 148  
Test Pt. 15\*, Run 80/1, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	R <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	R <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
30	—	.21	61	—	19.86	None	None	None
39	—	1.89	66	—	36.80			
40	—	.34	85	—	3.58			
53	—	2.39	95	—	5.80			
62	—	2.84						
74	—	1.50						
75	—	1.04						

\* Y coordinate location off by + 0.445 inch

Table 149  
Test Pt. 15\*, Run 81/1, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
30	—	.23	61	—	25.1	None	None	None
39	—	.26	66	—	45.7			
40	—	.46	85	—	4.46			
62	—	3.50	95	—	6.79			
63	—	.78	99	—	1.29			
74	—	2.15	100	—	1.46			
* Y coordinate location off by + 0.445 inch								

Table 150  
Test Pt. 15, Run 25/0, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
36	Out	—	60	.0577	—	None	None	None
50	.0022	—	61	—	21.57			
57	Out	—	66	—	40.02			
70	.0002	—	67	.1100	—			
82	.0034	—	72	—	Out			
83	.0002	—	73	—	Out			
93	.0006	—	77	.1916	—			
			78	—	118.35			
			79	.0659	—			
			85	—	9.49			
			87	.6354	—			
			88	Out	—			
			89	—	Out			
			95	—	4.12			
			96	.5602	—			
			97	—	Out			
			98	.0017	—			
			99	—	1.31			

Table 151  
Test Pt. 15, Run 26/0, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec
33	Out	—	73	—	Out	None	None	None
34	Out	—	89	—	Out			
35	.0034	—	97	—	Out			
47	Out	—	100	—	1.442			
48	.0132	—						
49	Out	—						
53	—	2.616						
55	.0136	—						
56	.0026	—						
62	—	3.19						
63	—	.978						
64	—	.144						
68	.0149	—						
69	Out	—						
74	—	2.056						
75	—	Out						
80	.0103	—						
81	.0106	—						
90	.0061	—						
91	.0125	—						
92	Out	—						

Table 152  
Test Pt. 17, Run 79/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec
39	—	.23	61	—	.65	None	None	None
40	—	.16	66	—	.83			
53	—	Out	72	—	1.23			
62	—	.09	73	—	3.95			
63	—	Out	77	.00948	—			
64	—	.20	78	—	15.87			
74	—	Out	79	.00159	—			
75	—	Out	85	—	Out			
90	.00042	—	87	Out	—			
91	.00049	—	88	.00397	—			
92	Out	—	89	—	33.29			
			95	—	.67			
			96	.08338	—			
			97	—	112.95			
			98	.00027	—			
			99	—	.35			
			100	—	.35			

Table 153  
Test Pt. 17, Run 79/1, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
39	—	.20	61	—	.63	None	None	None
40	—	.14	66	—	1.03			
53	—	.25	72	—	1.38			
62	—	.17	73	—	4.14			
63	—	.18	77	Out	—			
64	—	.13	78	—	12.31			
74	—	.13	79	Out	—			
75	—	.06	85	—	1.36			
90	Out	—	87	Out	—			
91	Out	—	88	Out	—			
92	Out	—	89	—	32.61			
			95	—	.66			
			96	Out	—			
			97	—	141.62			
			98	Out	—			
			99	—	.28			
			100	—	.33			

Table 154  
Test Pt. 17, Run 23/1, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	$\dot{q}$ Btu/ft <sup>2</sup> sec
33	.0009	—	60	.0035	—	None	None	None
34	Out	—	61	—	1.660.			
35	.0005	—	66	—	2.510			
36	.0001	—	67	Out	—			
47	.0009	—	72	—	4.520			
48	Out	—	73	—	7.580			
49	.0005	—	77	.0112	—			
			78	—	12.05			
			79	.0040	—			
			85	—	1.450			
			87	.0510	—			
			88	.0019	—			
			89	—	32.95			
			95	—	Out			
			96	.1429	—			
			97	—	77.56			
			98	.0009	—			
			99	—	.18			

Table 155  
Test Pt. 17, Run 24/0, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec
50	.0002	—	100	—	.24	None	None	None
51	.0002	—						
55	.0019	—						
56	.0004	—						
57	.0002	—						
58	.0000	—						
68	.0019	—						
69	.0013	—						
70	.0004	—						
71	.0001	—						
80	.0011	—						
81	.0017	—						
82	.0008	—						
83	.0001	—						
90	.0017	—						
91	.0011	—						
92	.0004	—						
93	.0001	—						
53	—	Out						
62	—	.54						
63	—	.18						
64	—	.07						
74	—	.30						
75	—	.15						

Table 156  
Test Pt. 17, Run 78/0, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
53	—	.59	61	—	2.81	None	None	None
62	—	.69	66	—	4.42			
63	—	.17	72	—	5.86			
64	—	Out	73	—	9.24			
74	—	Out	77	.02501	—			
75	—	Out	78	—	14.86			
90	Out	—	79	.00998	—			
91	Out	—	85	—	1.69			
92	Out	—	87	.05146	—			
			88	.00118	—			
			89	—	42.93			
			95	—	.94			
			96	.12304	—			
			97	—	91.22			
			98	Out	—			
			99	—	.33			
			100	—	.46			

Table 157  
Test Pt. 17, Run 78/1, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec
53	—	Out	61	—	2.91	None	None	None
62	—	.72	66	—	3.64			
63	—	Out	72	—	5.33			
64	—	.04	73	—	8.53			
74	—	.04	77	.01448	—			
75	—	Out	78	—	13.79			
90	.00080	—	79	.00257	—			
91	.00104	—	85	—	Out			
92	.00029	—	87	.05866	—			
			88	.00779	—			
			89	—	39.75			
			95	—	.24			
			96	.16412	—			
			97	—	84.90			
			98	.00030	—			
			99	—	.30			
			100	—	.30			

Table 158  
Test Pt. 17, Run 63/0, Vertical Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec
53	—	.17	61	—	.31	None	None	None
62	—	.18	66	—	1.03			
63	—	.10	72	—	2.21			
64	—	.08	73	—	5.31			
74	—	.17	77	.00575	—			
75	—	.04	78	—	8.96			
90	.00022	—	79	.00094	—			
			85	—	.97			
			87	Out	—			
			88	.00040	—			
			89	—	33.44			
			95	—	.53			
			96	.13300	—			
			97	—	Out			
			99	—	.16			
			100	—	.23			

Table 159  
Test Pt. 17, Run 64/0, Vertical Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
53	—	Out	61	—	.62	None	None	None
62	—	.20	66	—	1.63			
63	—	Out	72	—	2.57			
64	—	.10	73	—	5.54			
74	—	Out	77	.00696	—			
75	—	Out	78	—	10.05			
90	.00024	—	79	.00117	—			
			85	—	1.10			
			87	Out	—			
			88	.00054	—			
			89	—	35.16			
			95	—	.60			
			96	.14808	—			
			97	—	Out			
			99	—	.20			
			100	—	.00			

Table 160  
Test Pt. 29, Run 95/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec
None	None	None	61	—	.95	None	None	None
			66	—	1.49			
			72	—	4.60			
			73	—	8.82			
			7	.01551	—			
			78	—	16.71			
			79	.00402	—			
			85	—	1.15			
			87	.07677	—			
			88	.00184	—			
			95	—	.32			
			96	.21983	—			
			98	.00100	—			
			99	—	Out			
			100	—	.54			

Table 161  
Test Pt. 29, Run 95/1, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	R <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	R <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec
None	None	None	61	—	.87	None	None	None
			66	—	2.51			
			72	—	46.90			
			73	—	9.61			
			77	.01551	—			
			78	—	17.08			
			79	.00402	—			
			85	—	1.76			
			87	.07677	—			
			88	.00184	—			
			95	—	.84			
			96	.21983	—			
			98	.00100	—			
			99	—	Out			
			100	—	.41			

Table 162  
Test Pt. 29, Run 34/0, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
33	.0008	—	60	.0008	—	None	None	None
34	.0011	—	61	—	Out			
35	.0006	—	66	—	4.07			
36	Out	—	67	.0000	—			
47	.0019	—	72	—	10.02			
48	.0011	—	73	—	Out			
49	.0000	—	77	.0348	—			
			78	—	23.94			
			79	.0056	—			
			85	—	1.95			
			87	.0954	—			
			88	Out	—			
			89	—	Out			
			95	—	1.08			
			96	.3679	—			
			97	—	Out			
			98	.0021	—			
			99	—	.59			

Table 163  
Test Pt. 29, Run 35/1, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
50	.0002	—	100	—	0.50	None	None	None
51	.0001	—						
55	.0019	—						
56	.0004	—						
57	.0004	—						
58	.0001	—						
68	Out	—						
69	.0020	—						
70	.0007	—						
71	.0000	—						
80	Out	—						
81	Out	—						
82	Out	—						
83	.0001	—						
90	Out	—						
91	Out	—						
92	.0016	—						
93	.0001	—						
53	—	.56						
62	—	.69						
63	—	.15						
64	—	.07						
74	—	.40						
75	—	.39						

Table 164  
Test Pt. 29, Run 94/0, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
None	None	None	61	—	4.10	None	None	None
			66	—	6.81			
			72	—	8.90			
			73	—	14.32			
			77	.02506	—			
			78	—	24.93			
			79	.00690	—			
			85	—	2.28			
			87	.10380	—			
			88	.00314	—			
			95	—	1.17			
			96	.30190	—			
			98	.00189	—			
			99	—	.50			
			100	—	.57			

Table 165  
Test Pt. 29, Run 94/1, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
None	None	None	61	—	3.83	None	None	None
			66	—	7.61			
			72	—	8.21			
			73	—	12.25			
			77	.02368	—			
			78	—	19.81			
			79	.00628	—			
			85	—	1.69			
			87	.09757	—			
			88	.00297	—			
			95	—	.86			
			96	.25545	—			
			98	.00172	—			
			99	—	.36			
			100	—	.51			

Table 166  
Test Pt. 29, Run 93/0, Vertical Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
None	None	None	61	—	.99	None	None	None
			66	—	2.22			
			72	—	5.65			
			73	—	10.90			
			77	.01978	—			
			78	—	21.75			
			79	.00378	—			
			85	—	1.83			
			87	.08814	—			
			88	.00152	—			
			95	—	.94			
			96	.43793	—			
			98	.00068	—			
			99	—	.35			
			100	—	.45			

Table 167  
Test Pt. 29, Run 93/1, Vertical Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec
None	None	None	61	—	1.21	None	None	None
			66	—	2.64			
			72	—	5.28			
			73	—	10.54			
			77	.01823	—			
			78	—	16.80			
			79	.00369	—			
			85	—	1.62			
			87	.07616	—			
			88	.00131	—			
			95	—	.97			
			96	.43177	—			
			98	.00062	—			
			99	—	.36			
			100	—	.54			

Table 168  
Test Pt. 30, Run 84/0, Equivalent Engine Conf

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
None	None	None	61	—	19.36	None	None	None
			66	—	4.62			
			72	—	8.52			
			73	—	6.88			
			77	.01574	—			
			78	—	18.96			
			79	.00260	—			
			85	—	1.38			
			87	.04700	—			
			88	.00098	—			
			89	—	Out			
			95	—	.90			
			96	.14773	—			
			99	—	Out			
			100	—	.43			

Table 169  
Test Pt. 30, Run 84/1, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec
None	None	None	61	—	2.05	None	None	None
			66	—	4.38			
			72	—	10.34			
			73	—	Out			
			77	.01818	—			
			78	—	18.97			
			79	.00322	—			
			85	—	1.12			
			87	.04945	—			
			88	.00130	—			
			89	—	Out			
			95	—	1.01			
			96	.1506	—			
			99	—	Out			
			100	—	.41			

Table 170  
Test Pt. 30, Run 37/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
50	.0002	—	100	—	.428	None	None	None
51	.0008	—						
55	.0005	—						
56	.0002	—						
57	.0003	—						
58	.0003	—						
68	Out	—						
69	.0005	—						
70	.0004	—						
71	Out	—						
80	Out	—						
81	Out	—						
82	Out	—						
83	.0002	—						
90	.0005	—						
91	Out	—						
92	Out	—						
93	.0001	—						
53	—	.308						
62	—	.247						
63	—	.292						
64	—	.314						
74	—	.211						
75	—	.263						

Table 171  
Test Pt. 30, Run 36/0, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	$P_x$ psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	$P_x$ psia	$\dot{q}$ Btu/ft <sup>2</sup> sec	Sensor Number	$P_x$ psia	$\dot{q}$ Btu/ft <sup>2</sup> sec
33	.0026	—	60	Out	—	None	None	None
34	.0013	—	61	—	Out			
35	Out	—	66	—	22.34			
36	.0000	—	67	Out	—			
47	Out	—	72	—	16.90			
48	Out	—	73	—	2.38			
49	Out	—	77	.0306	—			
			78	—	33.31			
			79	.0038	—			
			85	—	1.86			
			87	.0920	—			
			88	.0021	—			
			89	—	Out			
			95	—	.103			
			96	.1366	—			
			97	—	Out			
			98	.0000	—			
			99	—	.265			

Table 172  
Test Pt. 30, Run 97/0, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
None	None	None	61	—	4.95	None	None	None
			66	—	8.33			
			72	—	12.51			
			73	—	Out			
			77	.03774	—			
			78	—	28.79			
			79	.00756	—			
			85	—	2.53			
			87	.09285	—			
			88	.00329	—			
			89	—	68.06			
			95	—	1.16			
			96	.27502	—			
			99	—	.48			
			100	—	.64			

Table 173  
Test Pt. 30, Run 97/1 Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
None	None	None	61	—	3.69	None	None	None
			66	—	6.11			
			72	—	8.49			
			73	—	8.10			
			77	.02653	—			
			78	—	19.71			
			79	.00479	—			
			85	—	1.81			
			87	.06221	—			
			88	.00194	—			
			89	—	45.30			
			95	—	.83			
			96	.17131	—			
			99	—	.30			
			100	—	.47			

Table 174  
Test Pt. 30, Run 83/0, Vertical Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
None	None	None	61	—	1.32	None	None	None
			66	—	4.31			
			72	—	7.96			
			73	—	7.15			
			77	.01456	—			
			78	—	18.57			
			79	.00230	—			
			85	—	1.78			
			87	.04639	—			
			88	.00086	—			
			89	—	56.08			
			95	—	.75			
			96	.18423	—			
			99	—	.26			
			100	—	.37			

Table 175  
Test Pt. 30, Run 83/1, Vertical Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
None	None	None	61	—	1.45	None	None	None
			66	—	3.82			
			72	—	7.20			
			73	—	7.62			
			77	.01258	—			
			78	—	17.91			
			79	.00172	—			
			85	—	1.45			
			87	.04731	—			
			88	.00070	—			
			89	—	Out			
			95	—	.05			
			96	.19754	—			
			99	—	.22			
			100	—	.34			

Table 176  
Test Pt. 31, Run 39/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
53	—	.373	78	—	Out	None	None	None
56	.0004	—	89	—	Out			
57	.0004	—	97	—	Out			
58	.0001	—	100	—	1.44			
62	—	.302						
63	—	Out						
64	—	.288						
68	Out	—						
69	Out	—						
70	Out	—						
71	.0000	—						
74	—	1.12						
75	—	.333						
80	.0015	—						
81	Out	—						
82	.0012	—						
83	.0001	—						
90	Out	—						
91	Out	—						
92	.0017	—						
93	.0001	—						

Table 177  
Test Pt. 31, Run 86/0, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q̇ Btu/ft <sup>2</sup> sec
None	None	None	61	—	9.17	None	None	None
			66	—	21.91			
			67	.03060	—			
			72	—	23.36			
			73	—	Out			
			77	.16903	—			
			78	—	Out			
			79	.03157	—			
			85	—	Out			
			87	.52619	—			
			88	.01795	—			
			95	—	3.29			
			96	.84323	—			
			98	.00800	—			
			99	—	Out			
			100	—	1.33			

Table 178  
Test Pt. 31, Run 86/1, Equivalent Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
None	None	None	61	—	8.45	None	None	None
			66	—	20.35			
			67	.03781	—			
			72	—	19.97			
			73	—	Out			
			77	.19302	—			
			78	—	Out			
			79	.04086	—			
			85	—	1.85			
			87	.72373	—			
			88	.02567	—			
			95	—	.74			
			96	1.05454	—			
			98	.00869	—			
			99	—	.21			
			100	—	.32			

Table 179  
Test Pt. 31, Run 38/0, Horizontal Two-Engine Conf.

Fuselage			Tail			Wing		
Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec	Sensor Number	P <sub>x</sub> psia	q Btu/ft <sup>2</sup> sec
68	Out	—	60	Out	—	None	None	None
80	Out	—	61	—	9.16			
81	Out	—	66	—	23.59			
82	.0022	—	67	.0464	—			
90	.0039	—	72	—	30.40			
91	.0084	—	73	—	Out			
92	.0054	—	77	.1554	—			
93	.0002	—	78	—	Out			
			79	.0233	—			
			85	—	5.50			
			87	.6110	—			
			88	.0238	—			
			89	—	Out			
			95	—	1.99			
			96	1.223	—			
			97	—	Out			
			99	—	.773			

**Appendix B**  
**FIGURES**

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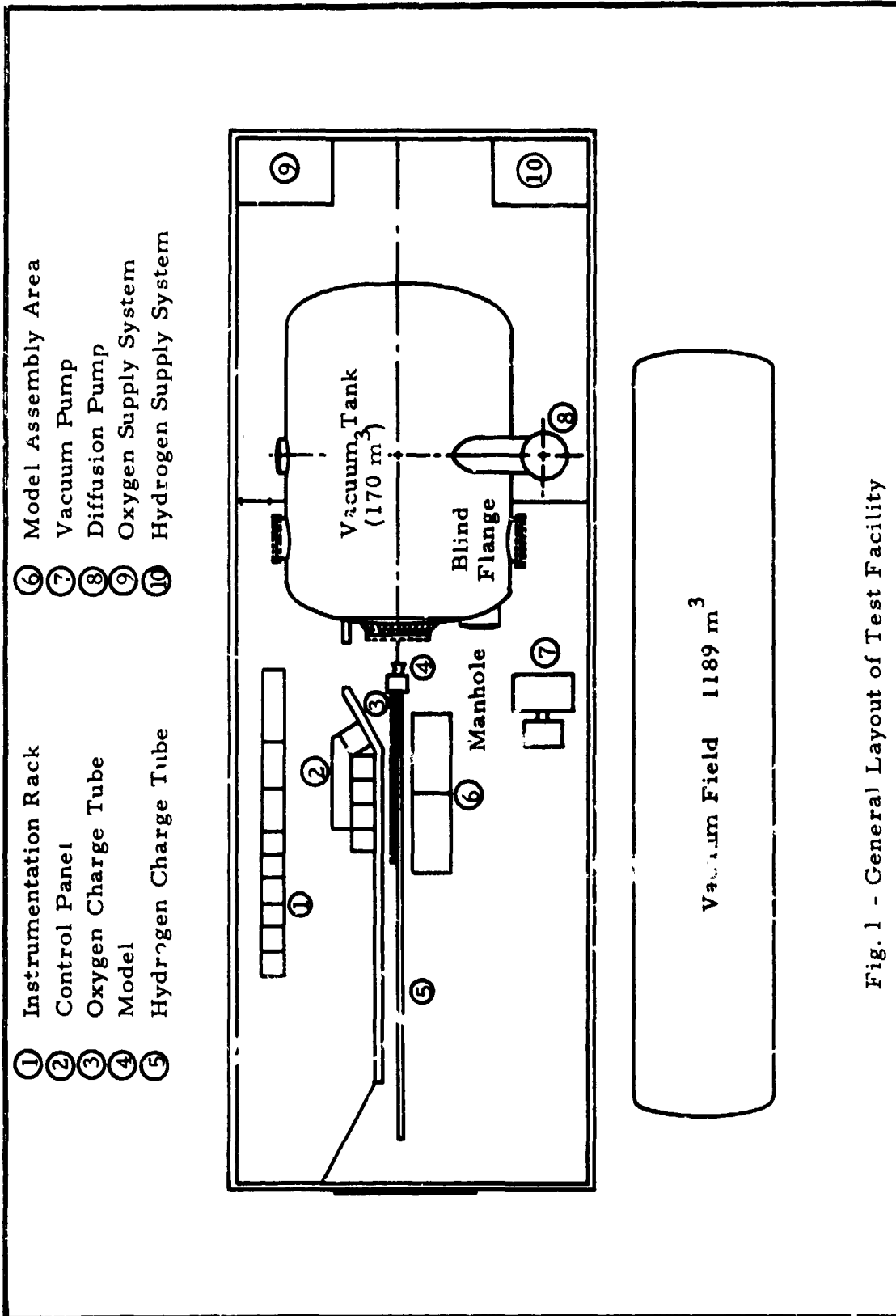
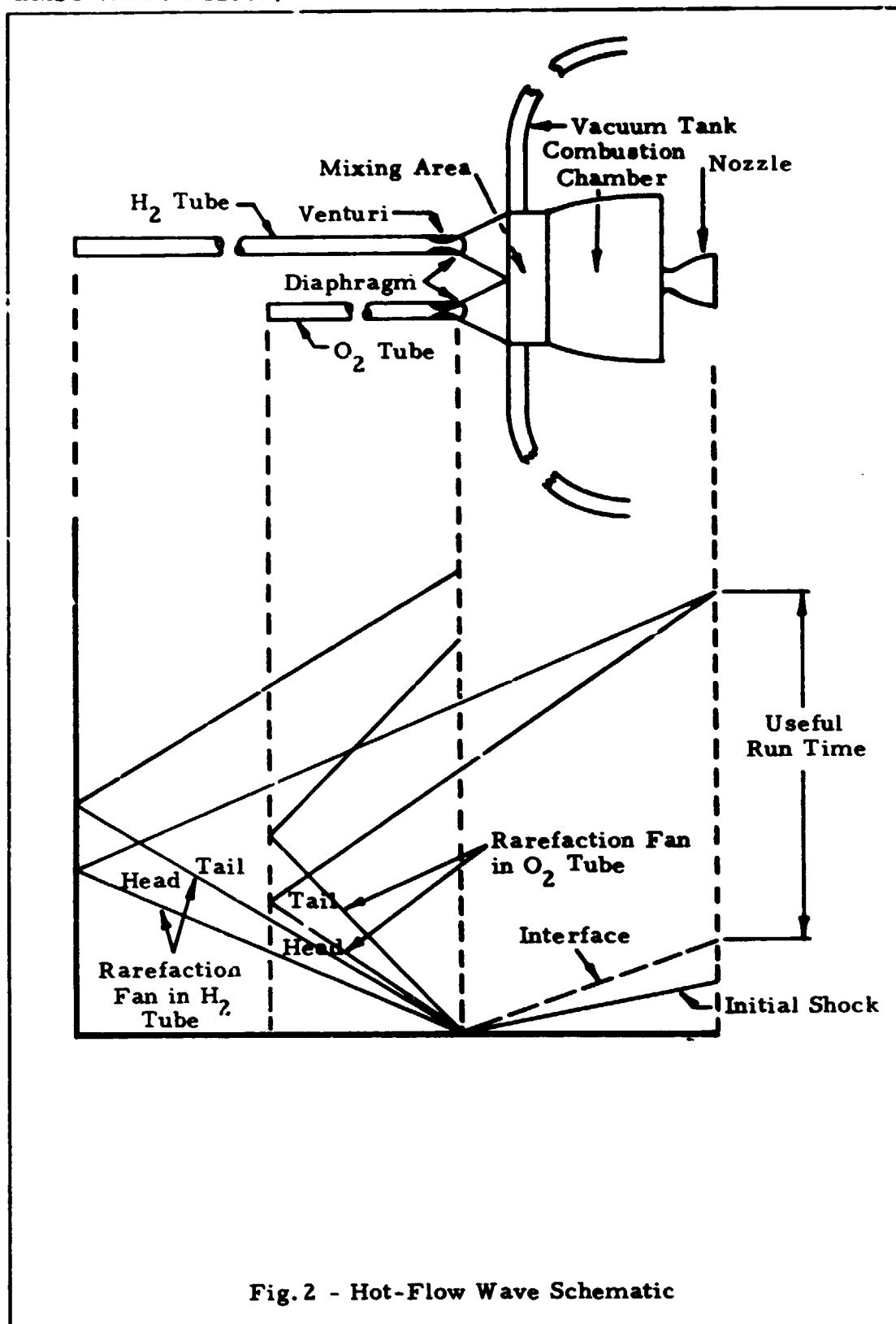


Fig. 1 - General Layout of Test Facility



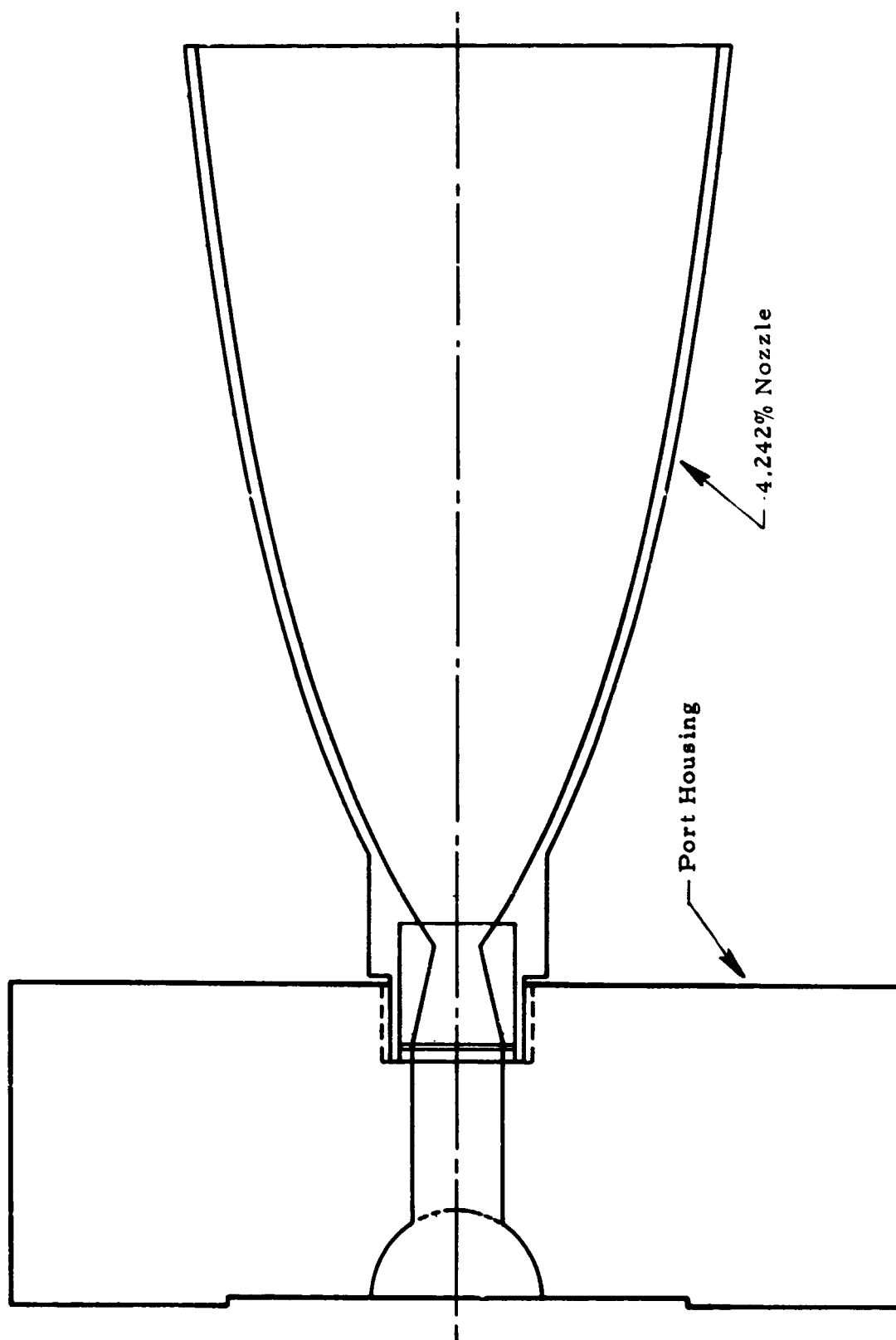


Fig. 3 - Schematic of 4.242% Nozzle

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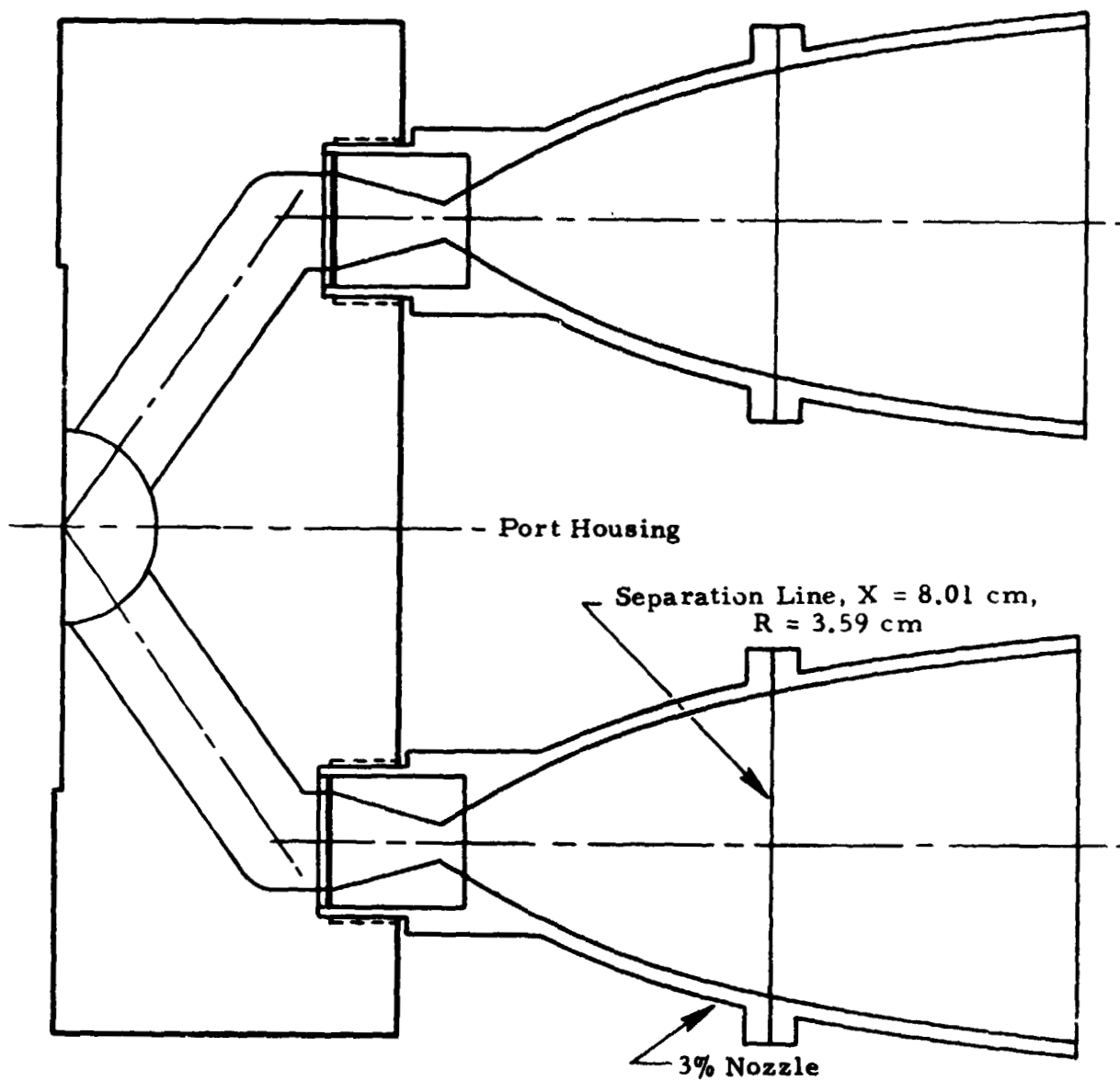


Fig. 4 - Schematic of 3% Nozzle Contour

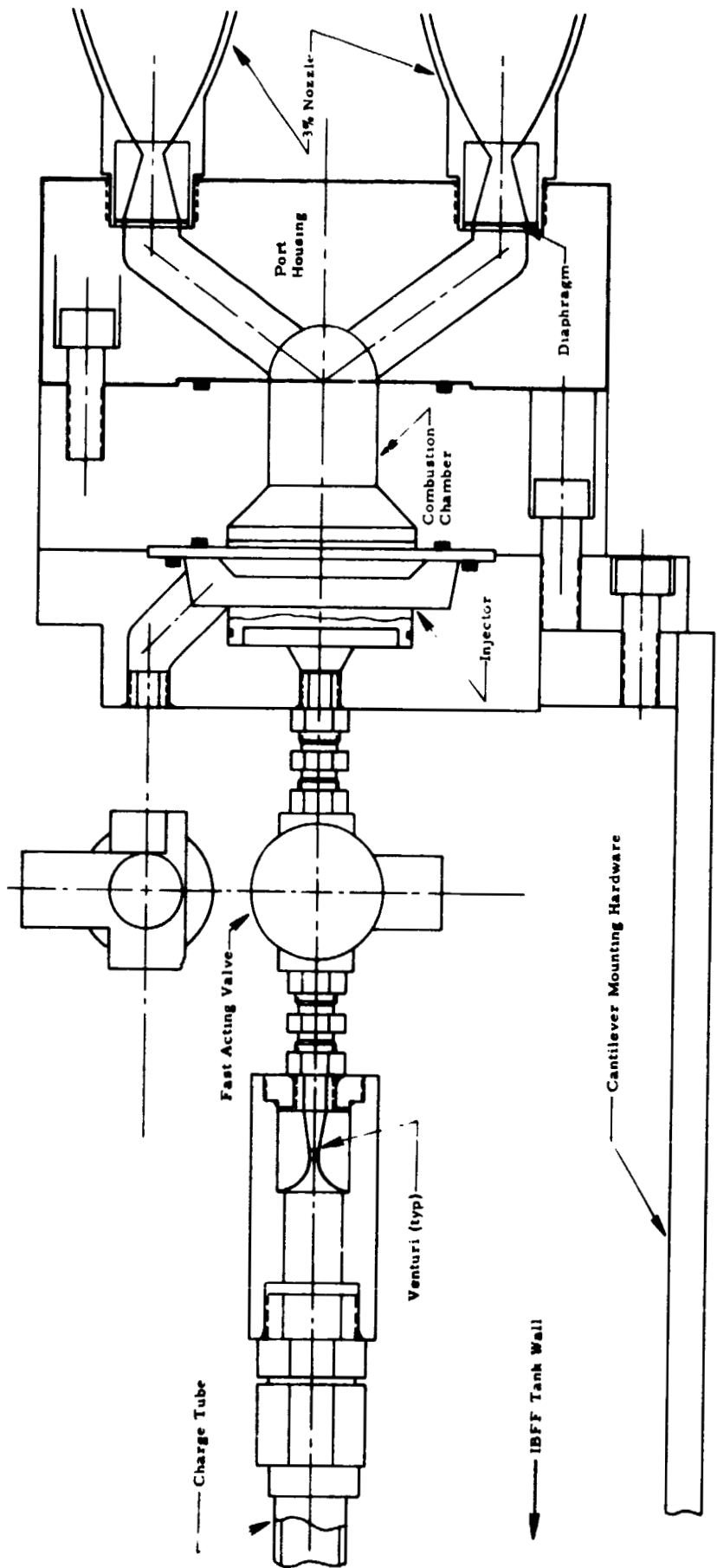
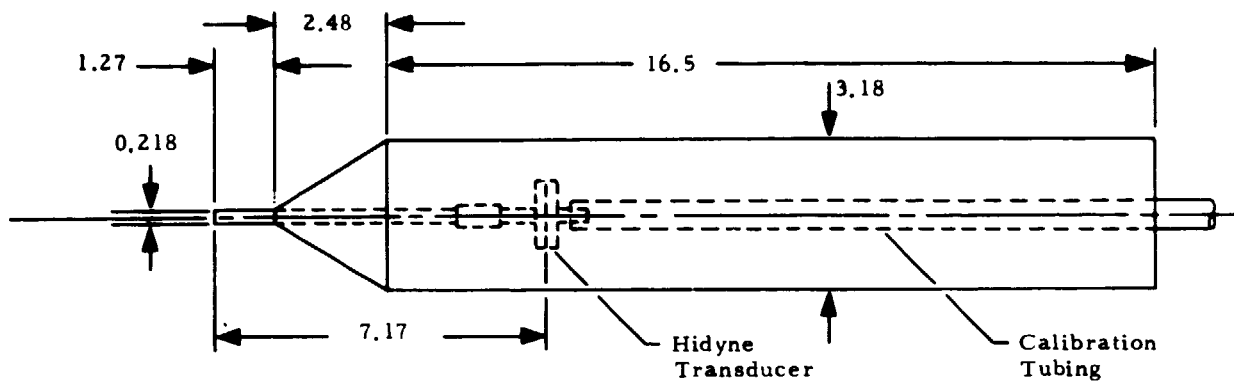
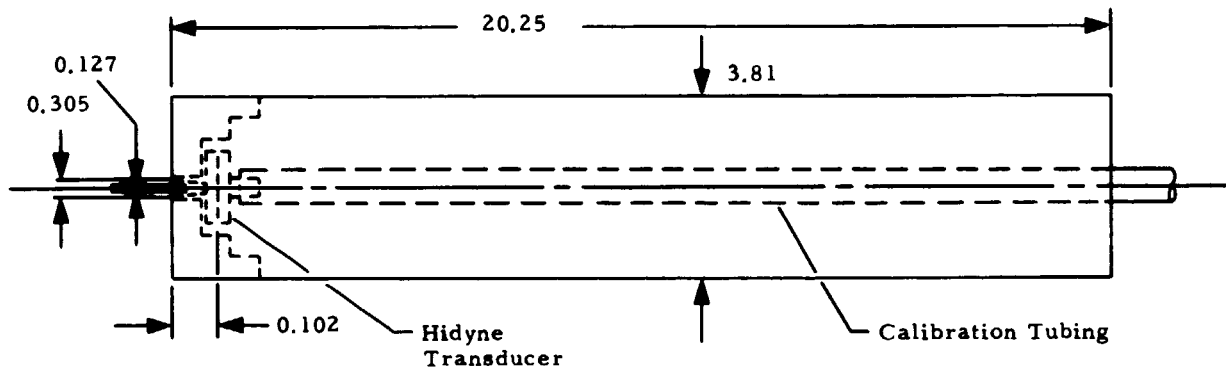


Fig. 5 - Schematic of Engine Hardware

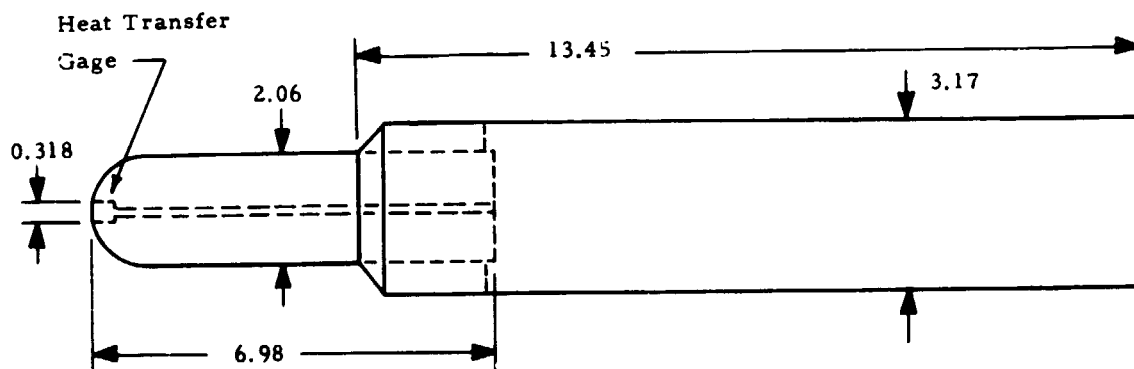


Probe A

All dimensions in centimeters



Probe B



Heat Transfer Probe

Fig. 6 - Schematic of Typical IBFF Probes

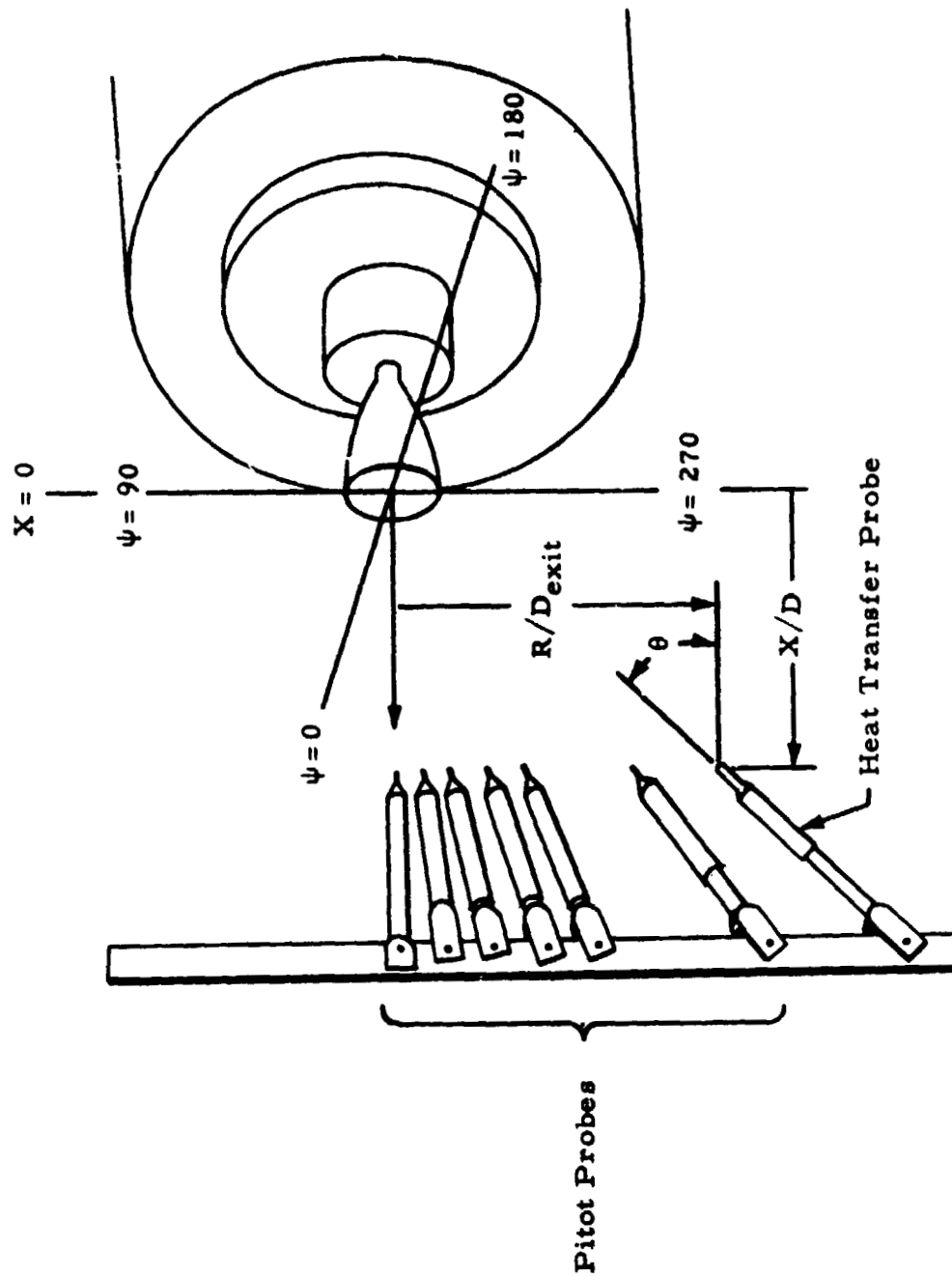


Fig. 7 - Nozzle/Impact Probe Axis System

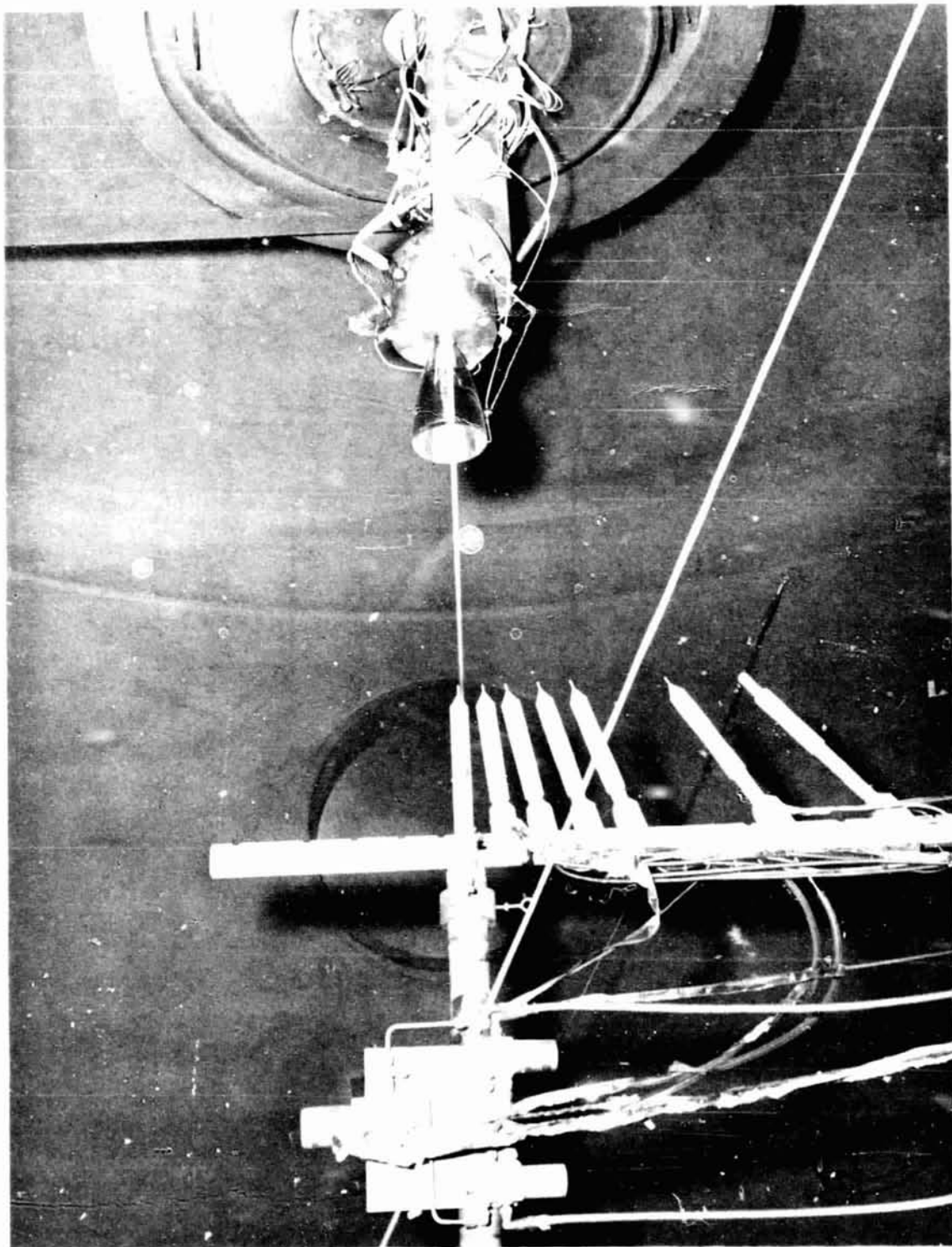


Fig. 8 - Equivalent Engine Plume Survey Arrangement

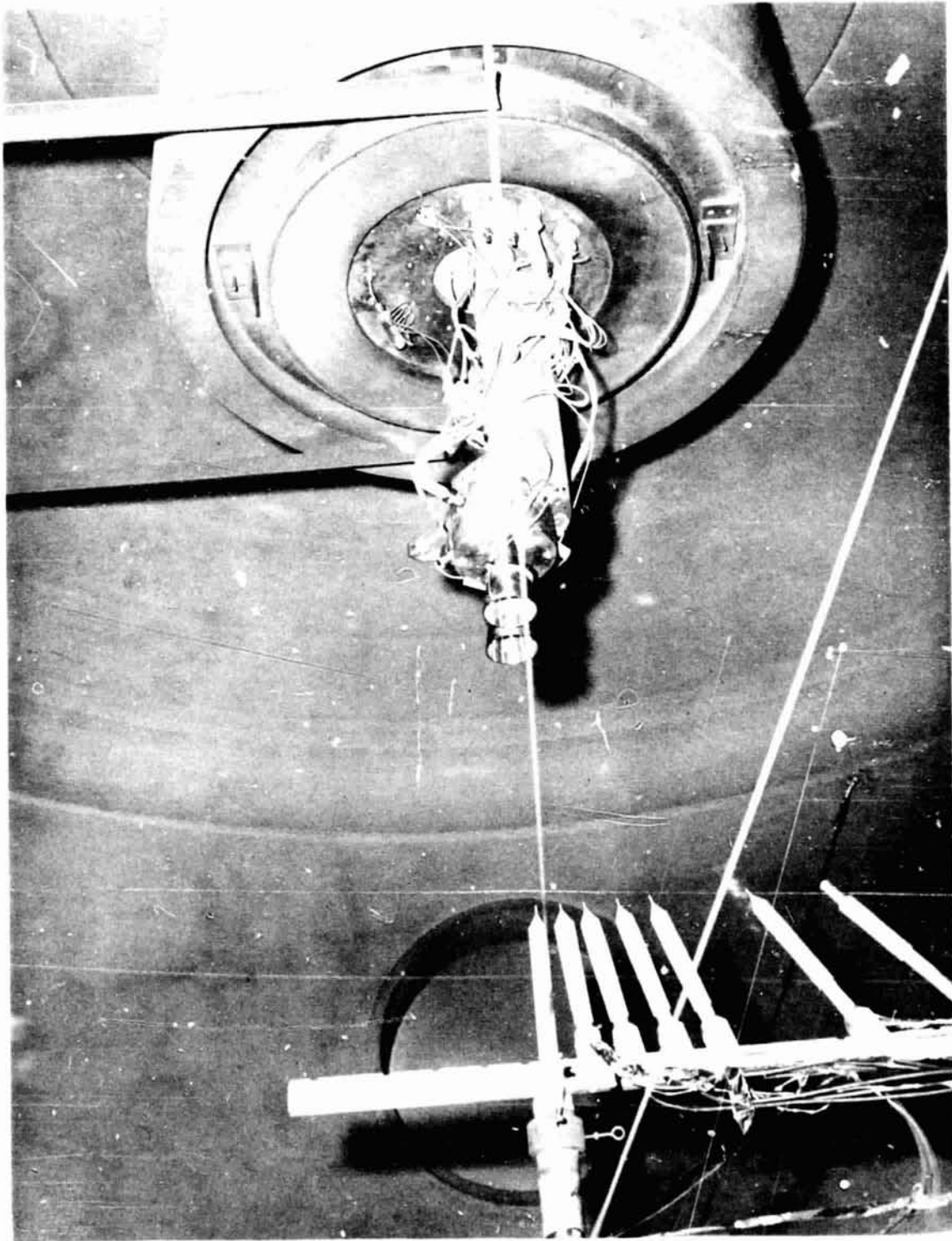


Fig. 9 - Dual Horizontal Configuration

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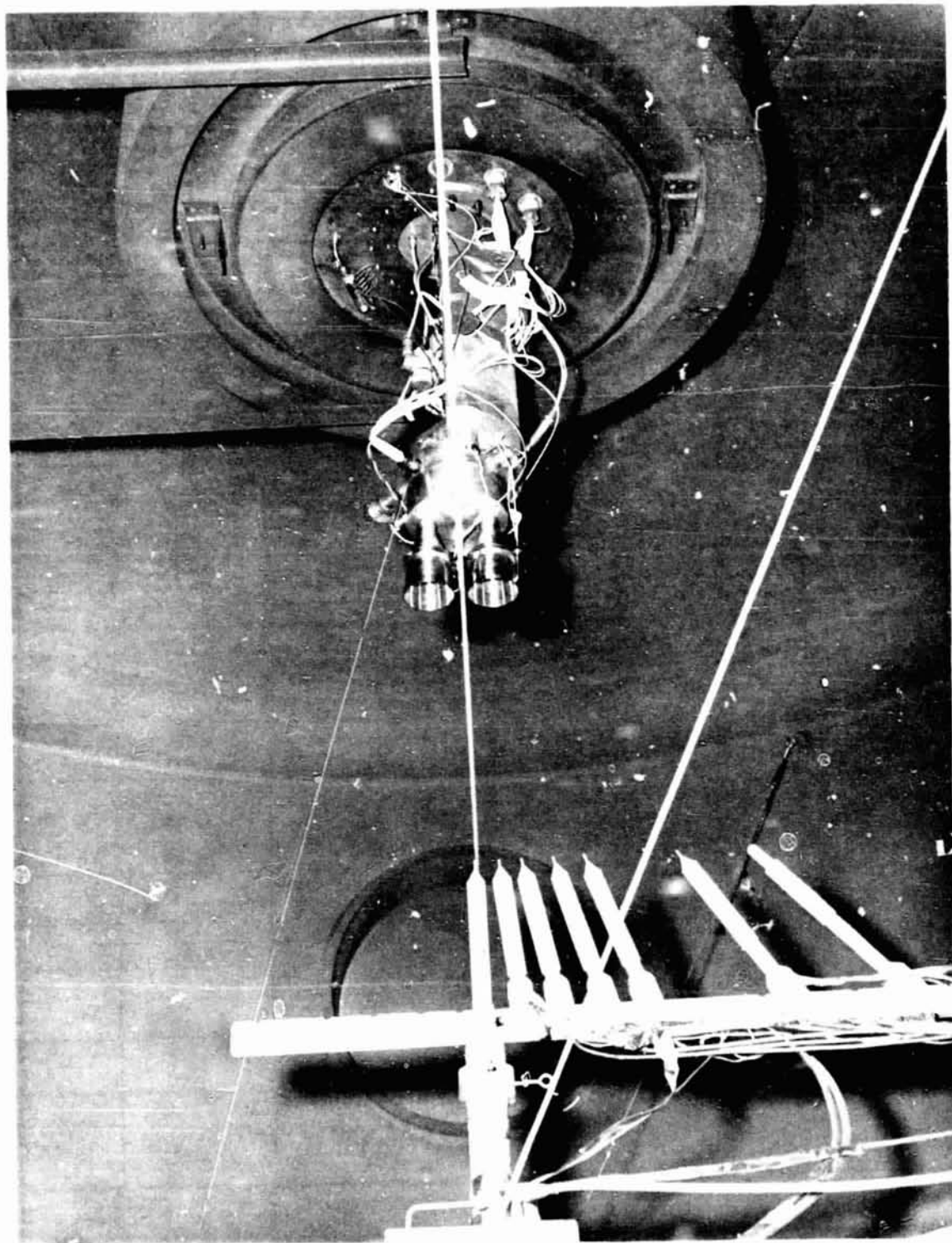


Fig. 10 - Dual Vertical Configuration

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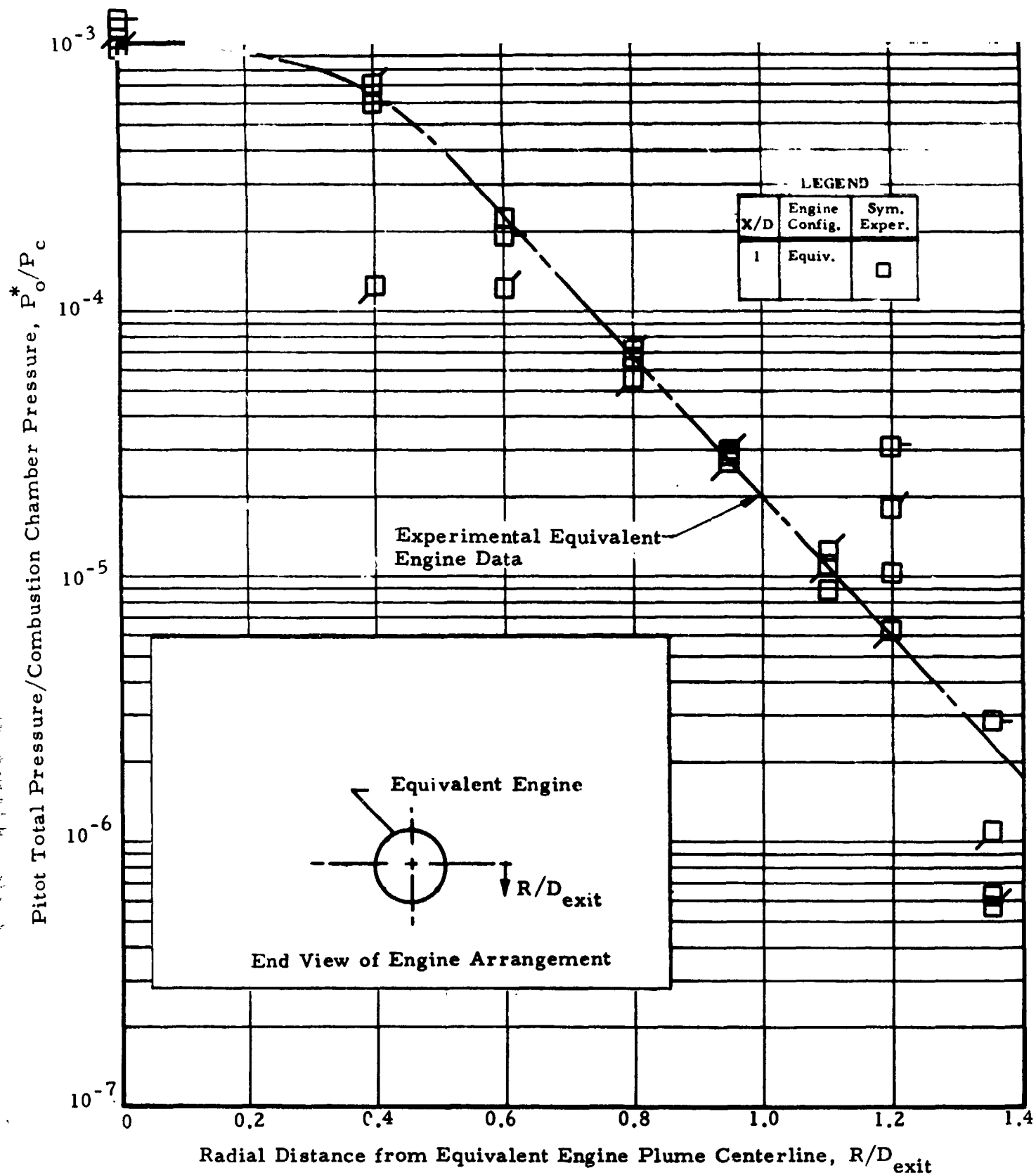
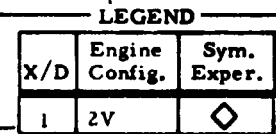


Fig. 11 - Radial Distribution of the Pitot Total Pressure in the Orbiter Main Engine Exhaust Plume at  $X/D = 1$  from the Engine Exit Plane (Equivalent Engine)



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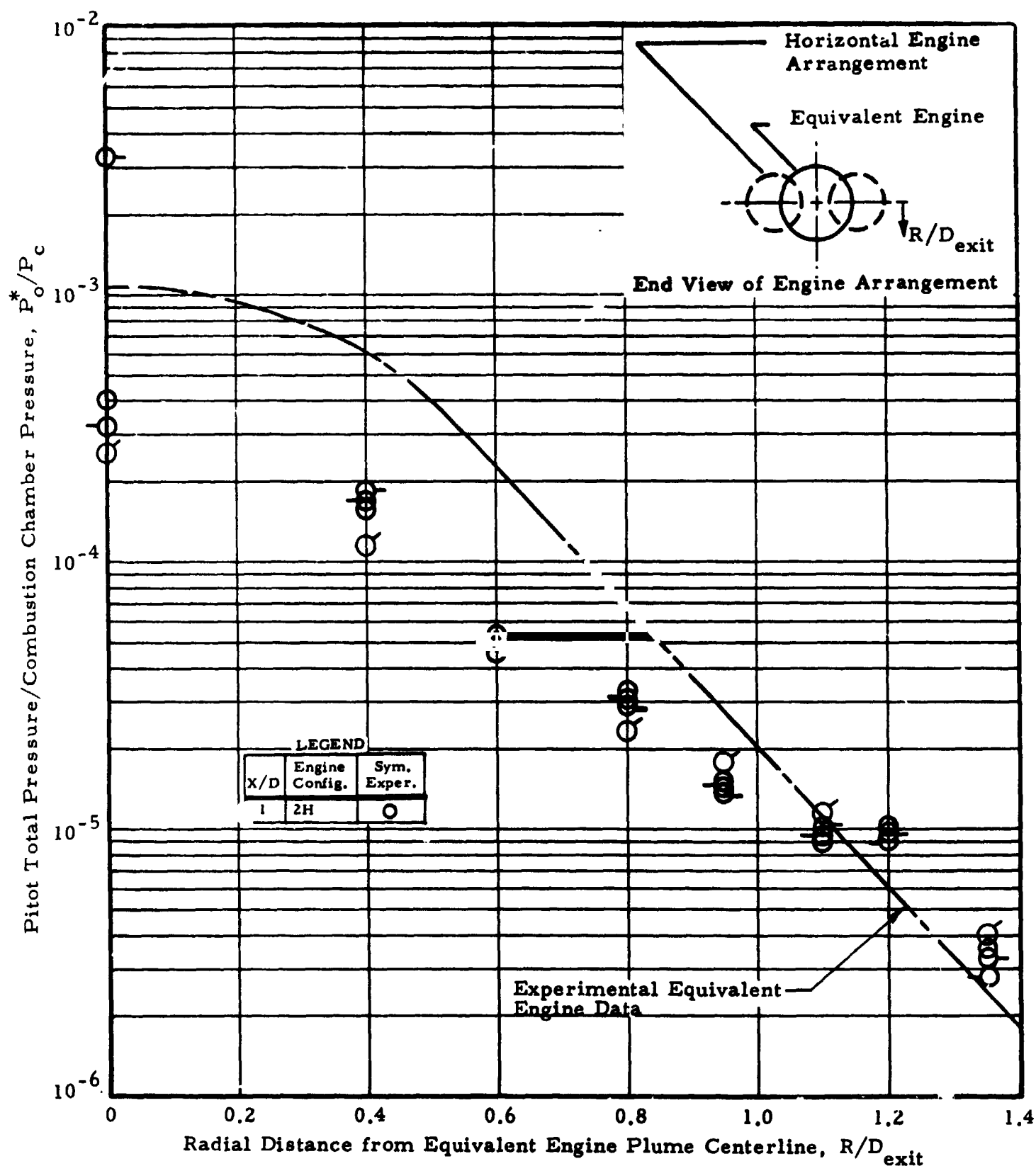


Fig. 13 - Radial Distribution of the Pitot Total Pressure in the Orbiter Main Engine Exhaust Plume at  $X/D = 1$  from the Engine Exit Plane (Horizontal Engine Arrangement)

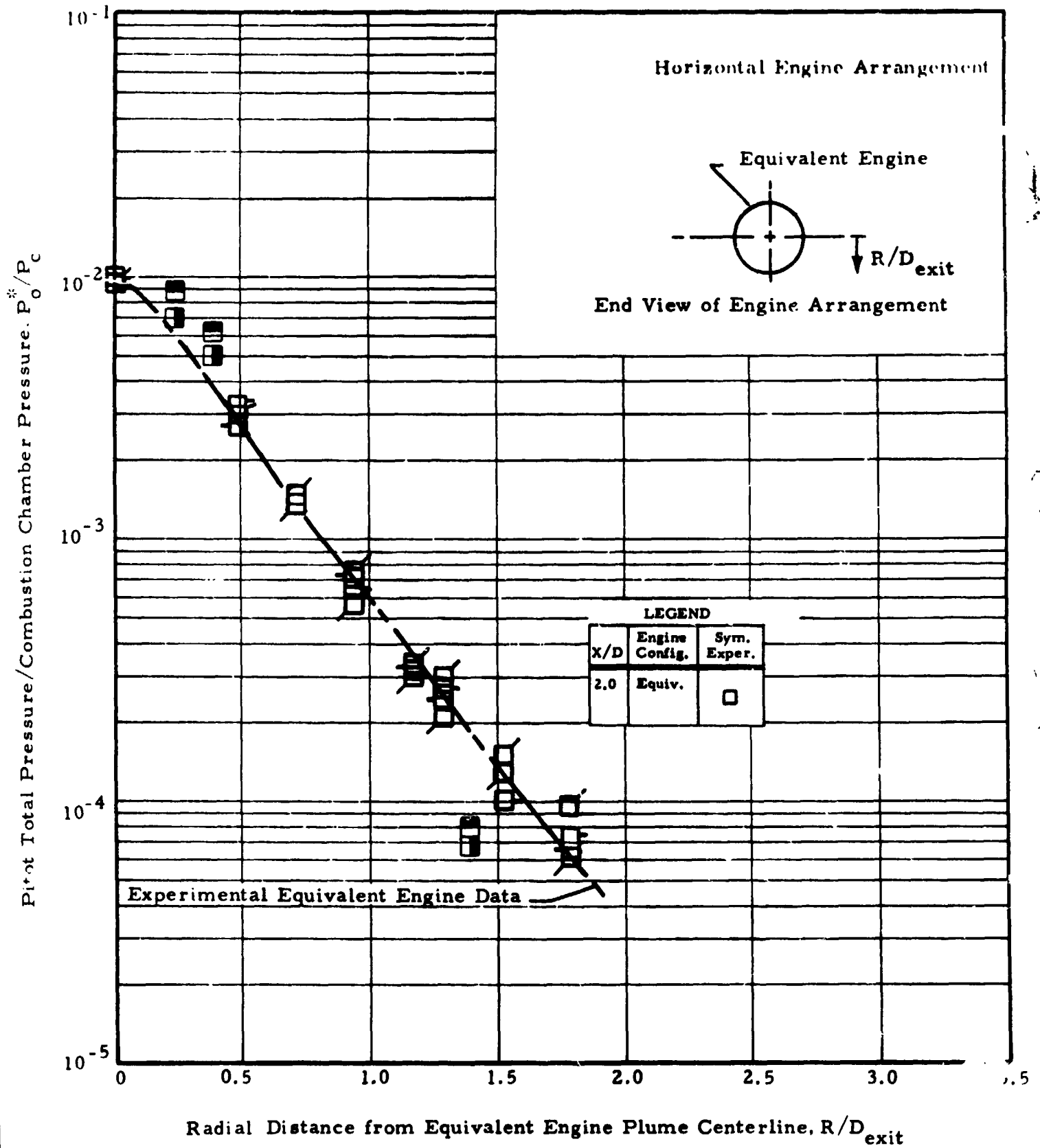


Fig. 14 - Radial Distribution of the Pitot Total Pressure in the Orbiter Main Engine Exhaust Plume at  $X/D = 2$  from the Engine Exit Plane (Equivalent Engine)

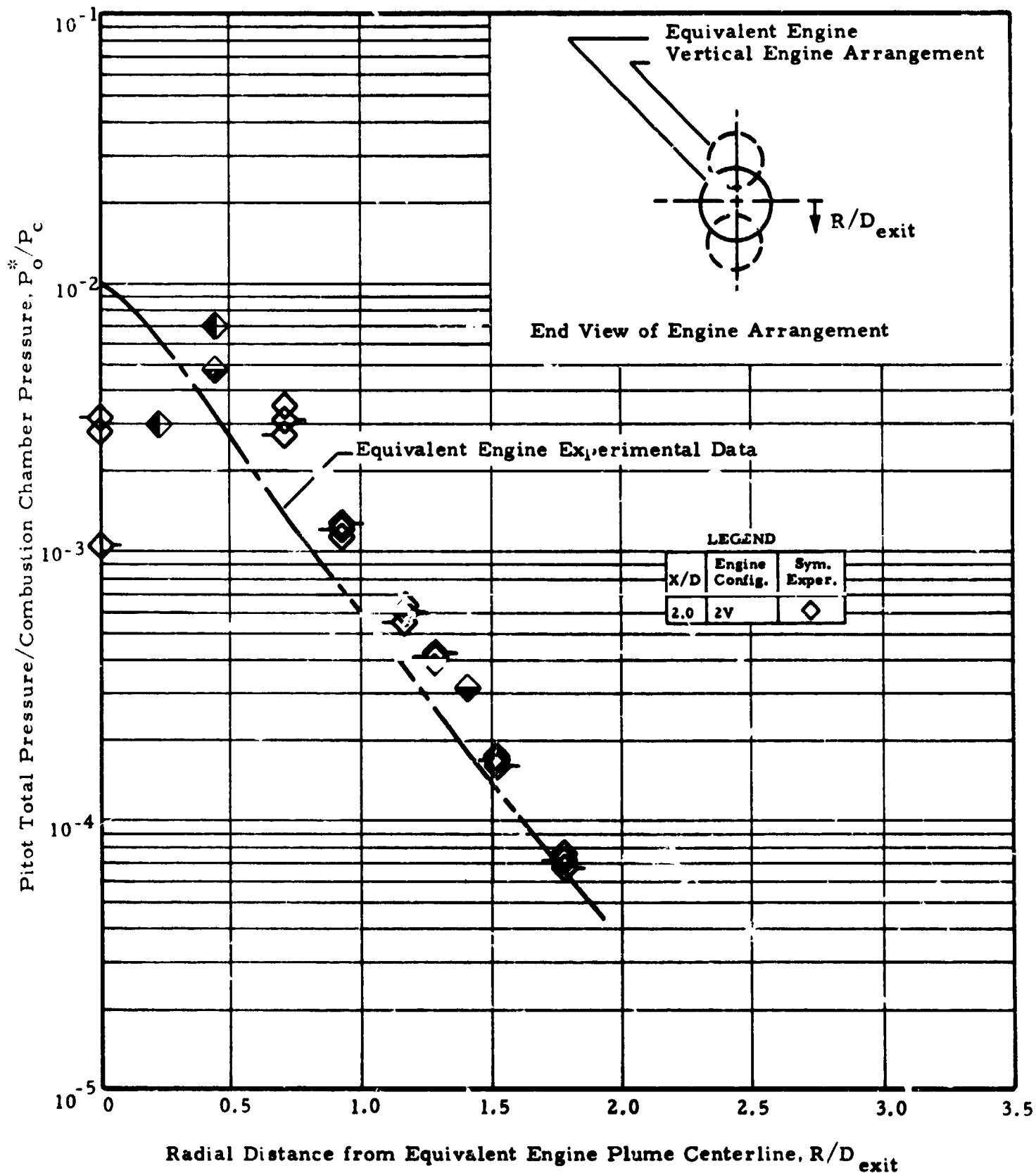


Fig. 15 - Radial Distribution of the Pitot Total Pressure in the Orbiter Main Engine Exhaust Plume at  $X/D = 2$  from the Engine Exit Plane (Vertical Engine Arrangement)

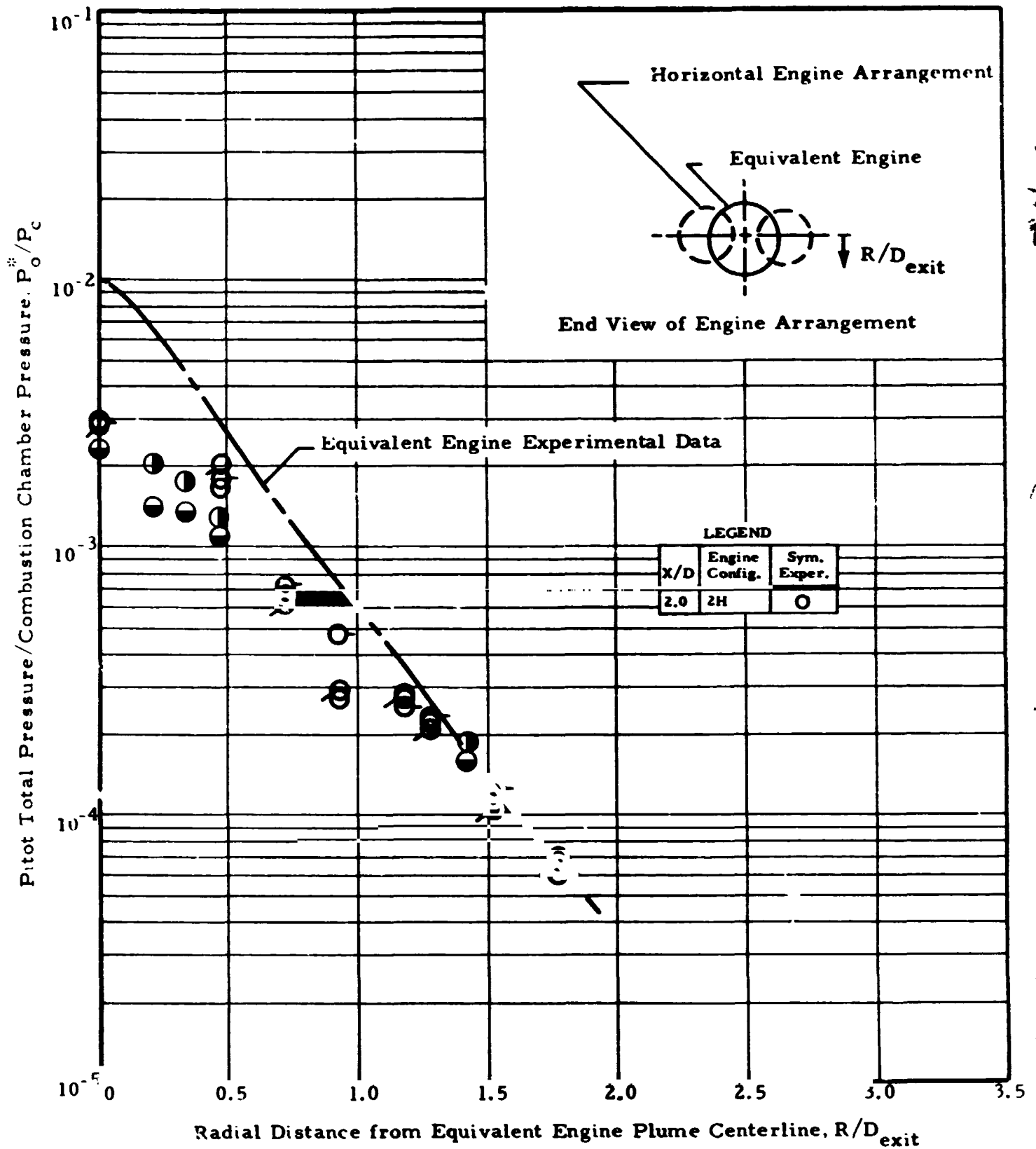


Fig. 16 - Radial Distribution of the Pitot Total Pressure in the Orbiter Main Engine Exhaust Plume at  $X/D = 2$  from the Engine Exit Plane (Horizontal Engine Arrangement)

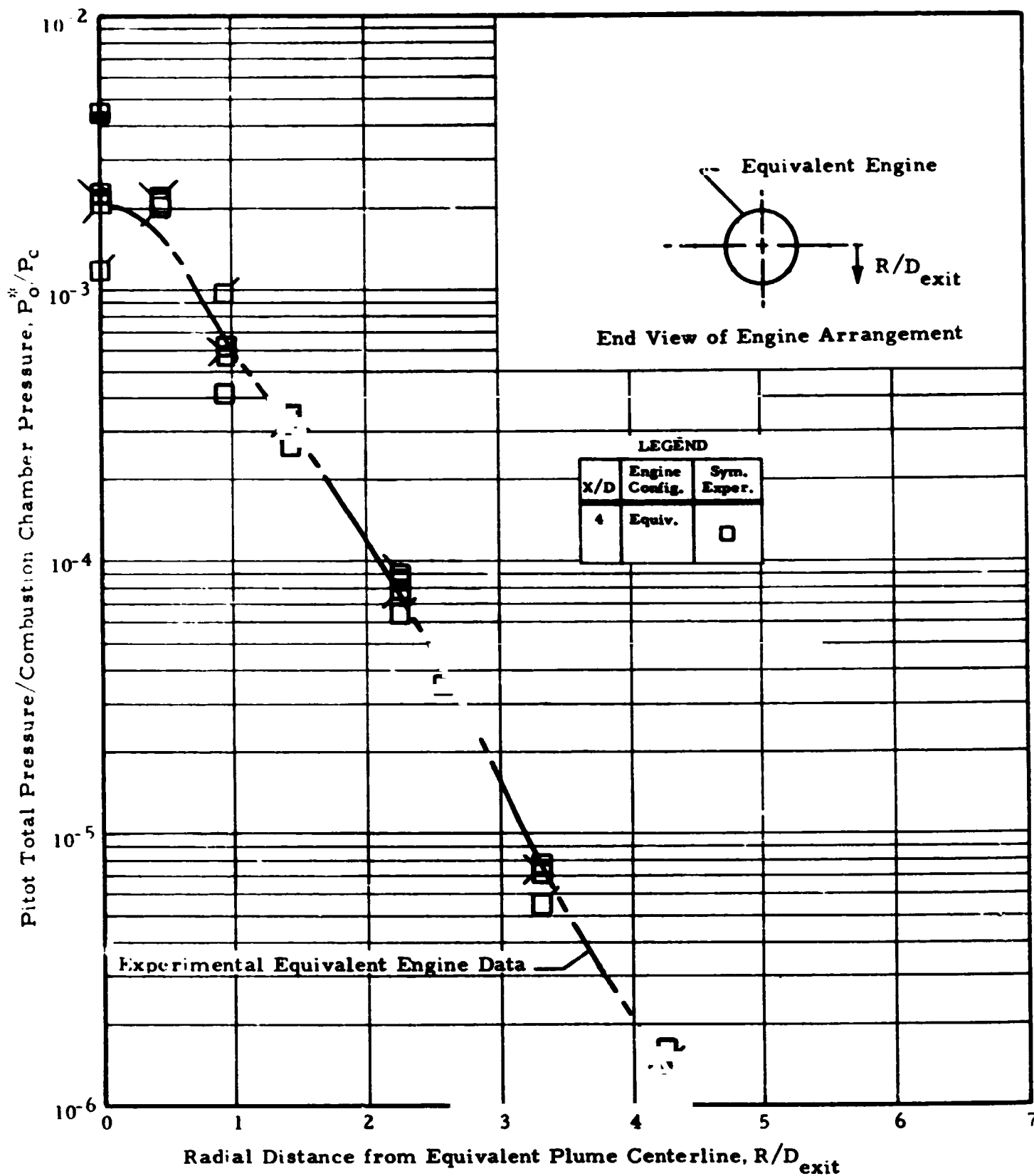


Fig. 17 - Radial Distribution of the Pitot Total Pressure in the Orbiter Main Engine Exhaust Plume at  $X/D = 4$  from the Engine Exit Plane (Equivalent Engine)

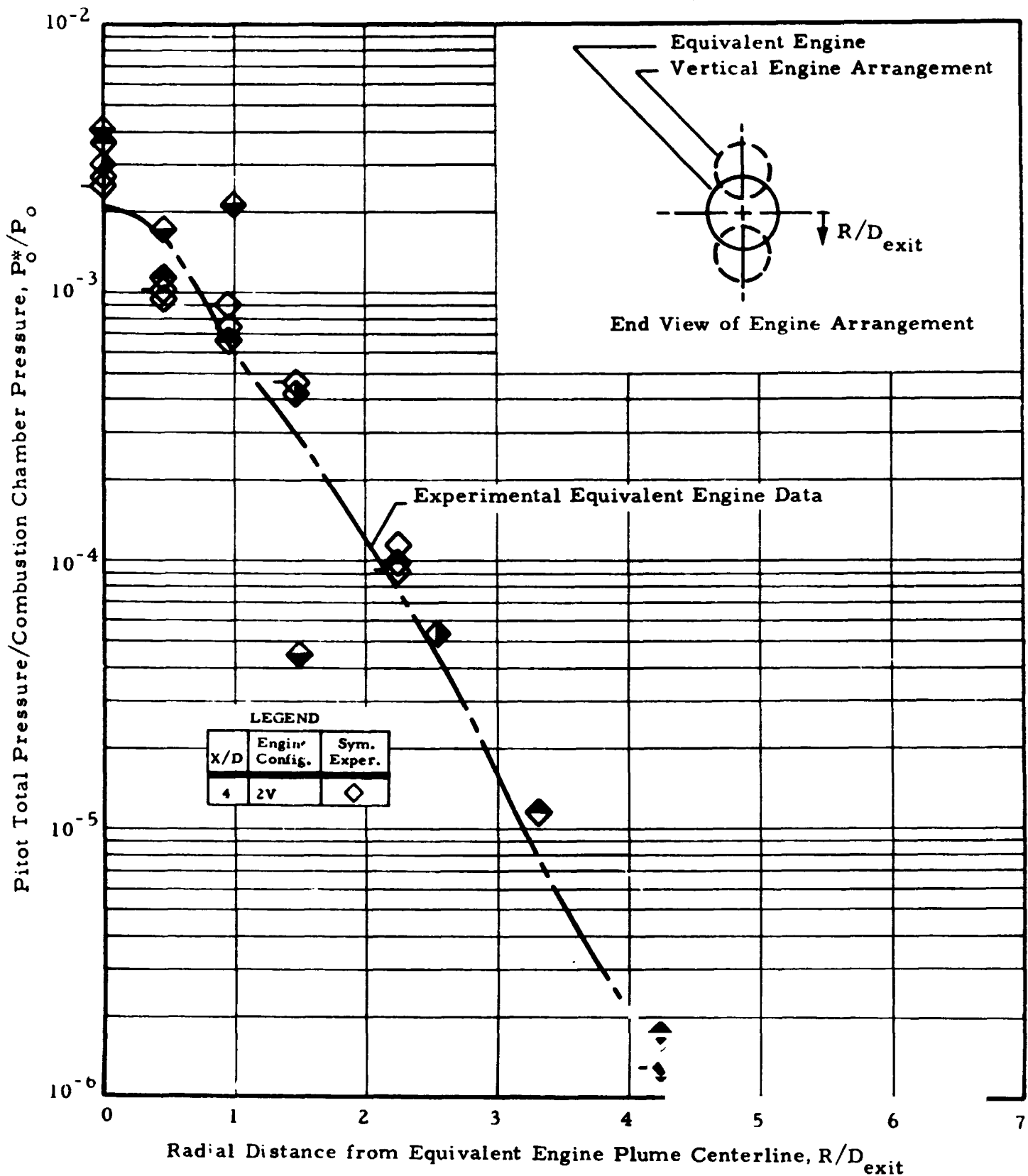


Fig. 18 - Radial Distribution of the Pitot Total Pressure in the Orbiter Main Engine Exhaust Plume at  $X/D = 4$  from the Engine Exit Plane (Vertical Engine Arrangement)

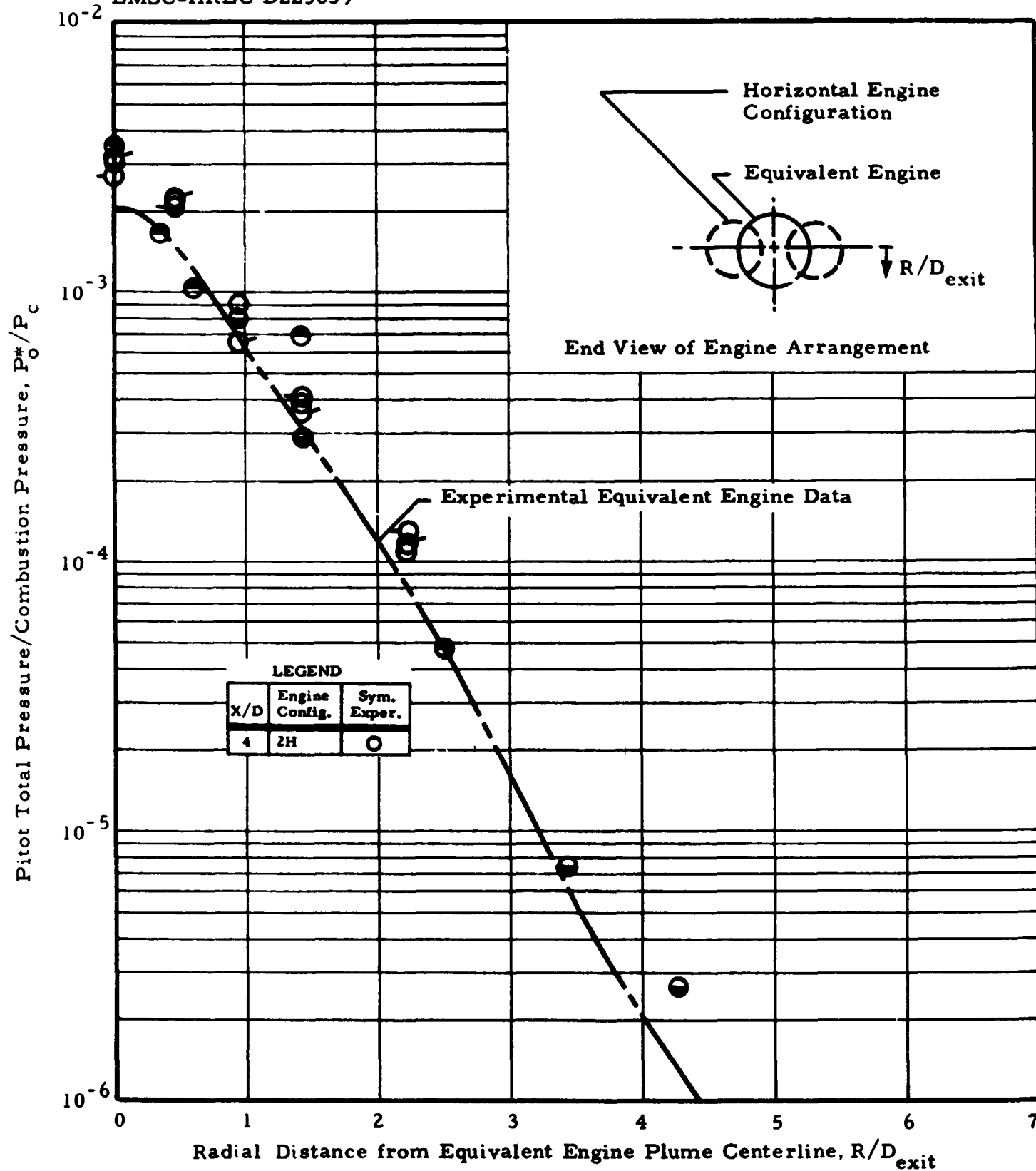


Fig. 19 - Radial Distribution of the Pitot Total Pressure in the Orbiter Main Engine Exhaust Plume at  $X/D = 4$  from the Engine Exit Plane (Horizontal Engine Arrangement)

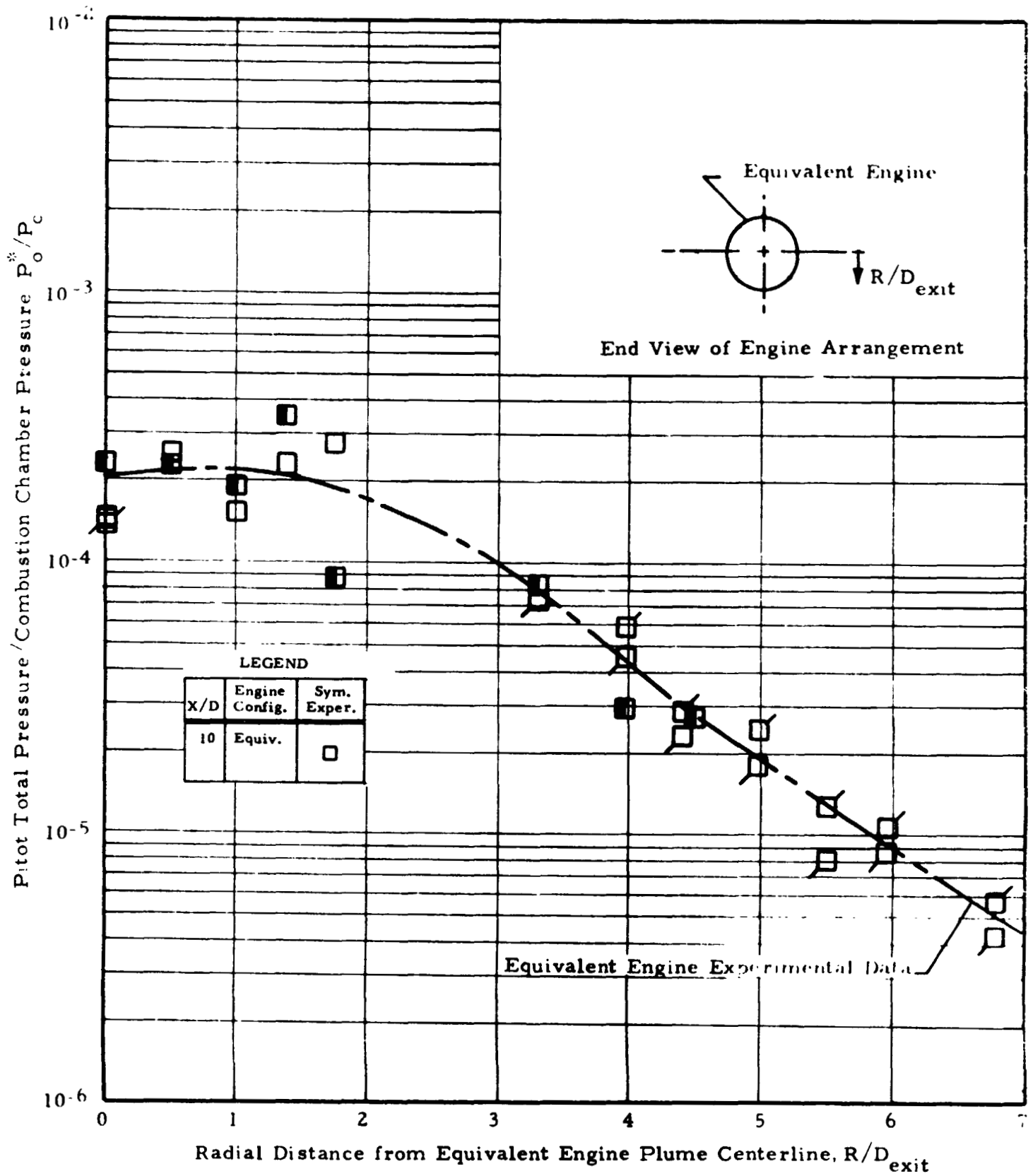


Fig. 20 - Radial Distribution of the Pitot Total Pressure in the Orbiter Main Engine Exhaust Plume at  $X/D = 10$  from the Engine Exit Plane (Equivalent Engine)

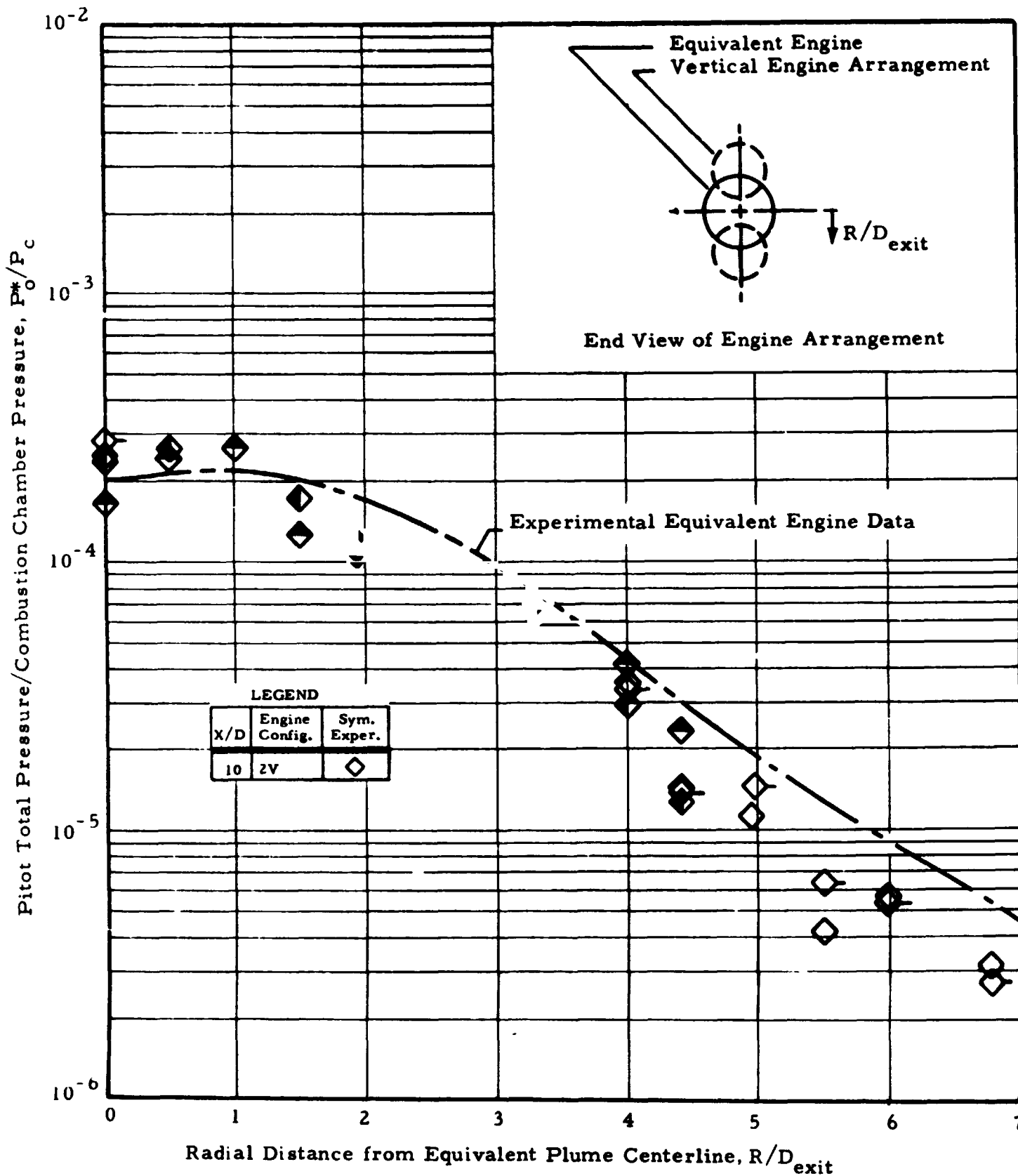


Fig. 21 - Radial Distribution of the Pitot Total Pressure in the Orbiter Main Engine Exhaust Plume at  $X/D = 10$  from the Engine Exit Plane (Vertical Engine Arrangement)

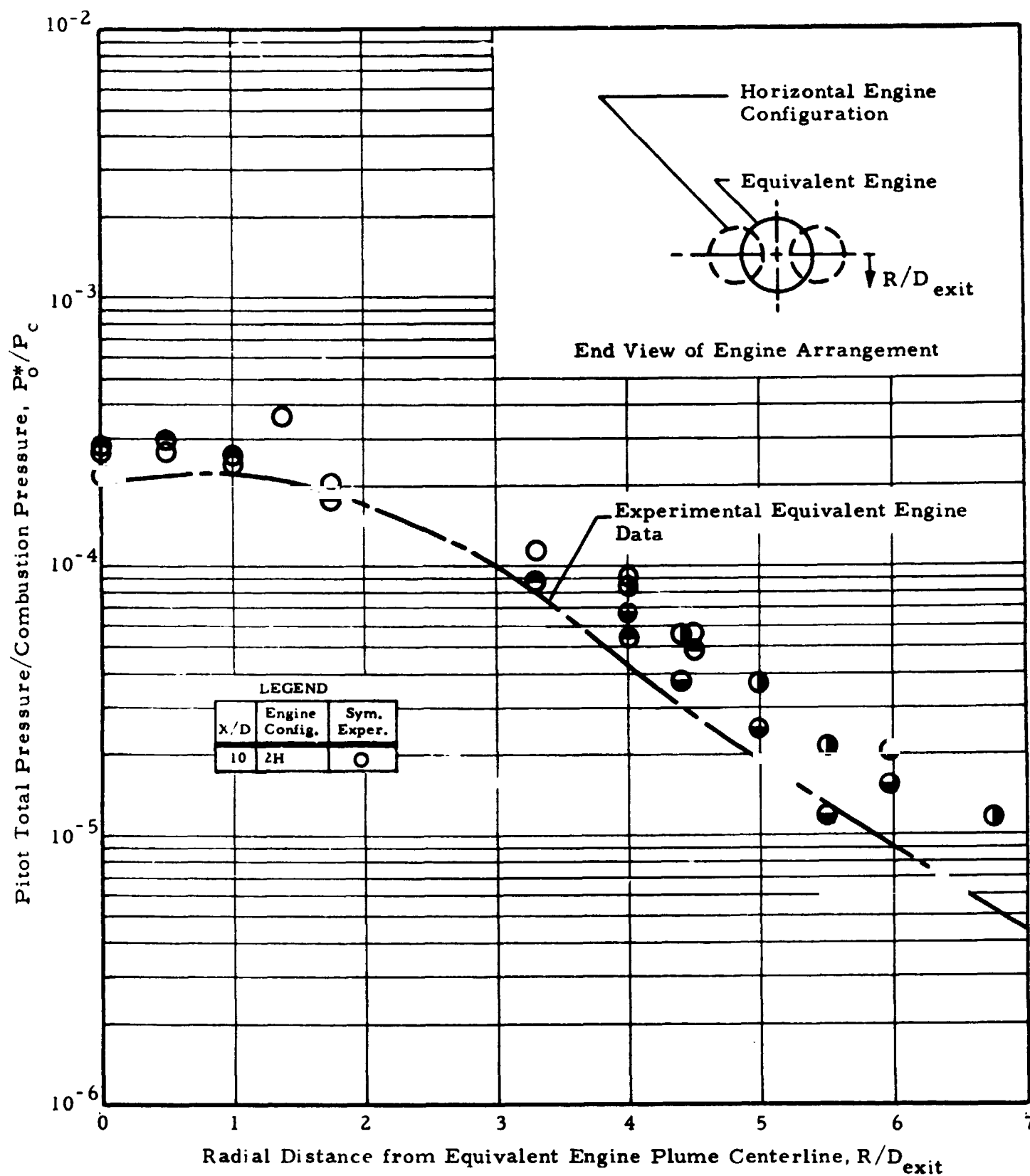


Fig. 22 - Radial Distribution of the Pitot Total Pressure in the Orbiter Main Engine Exhaust Plume at  $X/D = 10$  from the Engine Exit Plane (Horizontal Engine Arrangement)

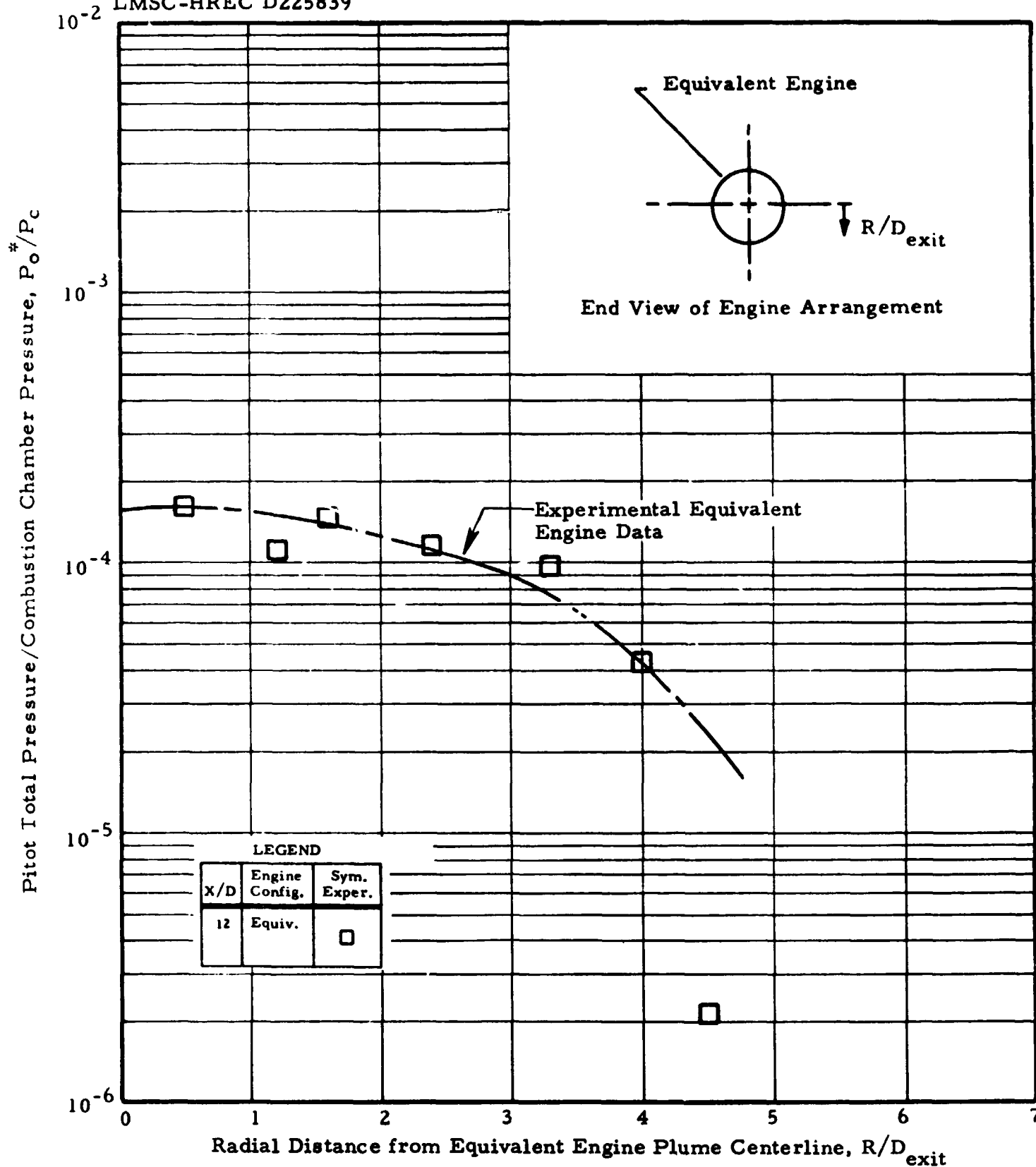


Fig. 23 - Radial Distribution of the Pitot Total Pressure in the Orbiter Main Engine Exhaust Plume at  $X/D = 12$  from the Engine Exit Plane (Equivalent Engine)

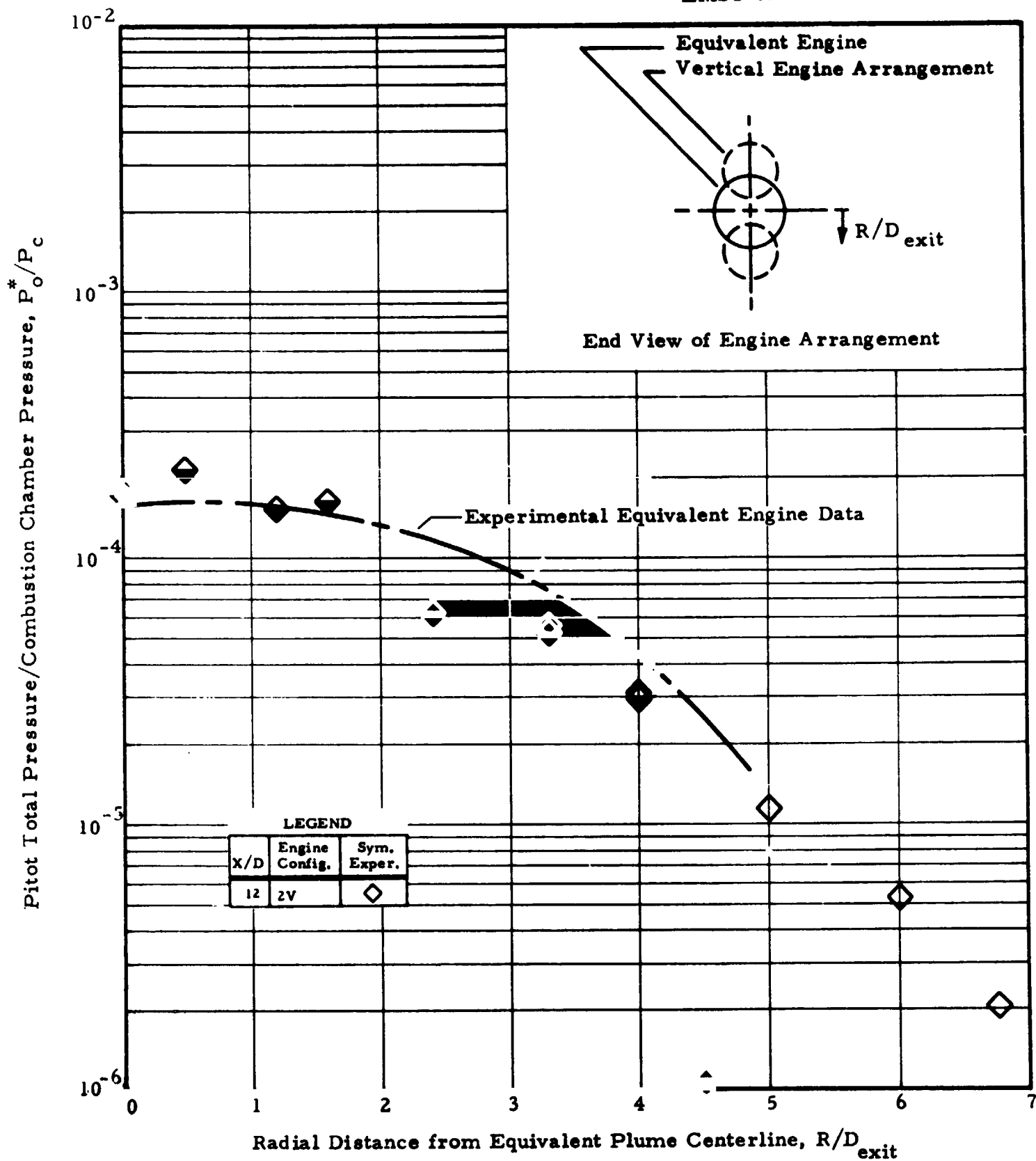


Fig. 24 - Radial Distribution of the Pitot Total Pressure in the Orbiter Main Engine Exhaust Plume at  $X/D = 12$  from the Engine Exit Plane (Vertical Engine Arrangement)

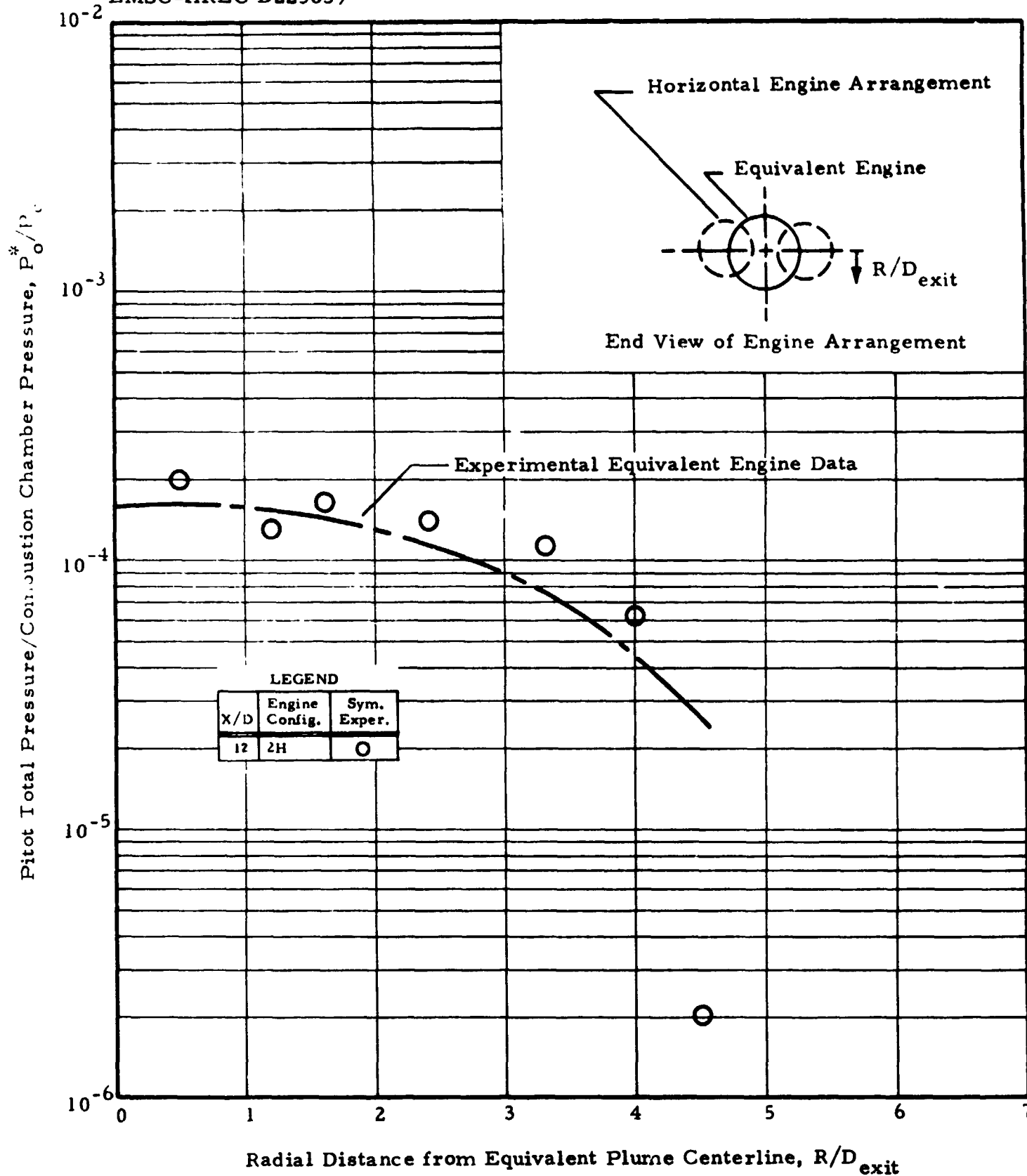


Fig. 25 - Radial Distribution of the Pitot Total Pressure in the Orbiter Main Engine Exhaust Plume at  $X/D = 12$  from the Engine Exit Plane (Horizontal Engine Arrangement)

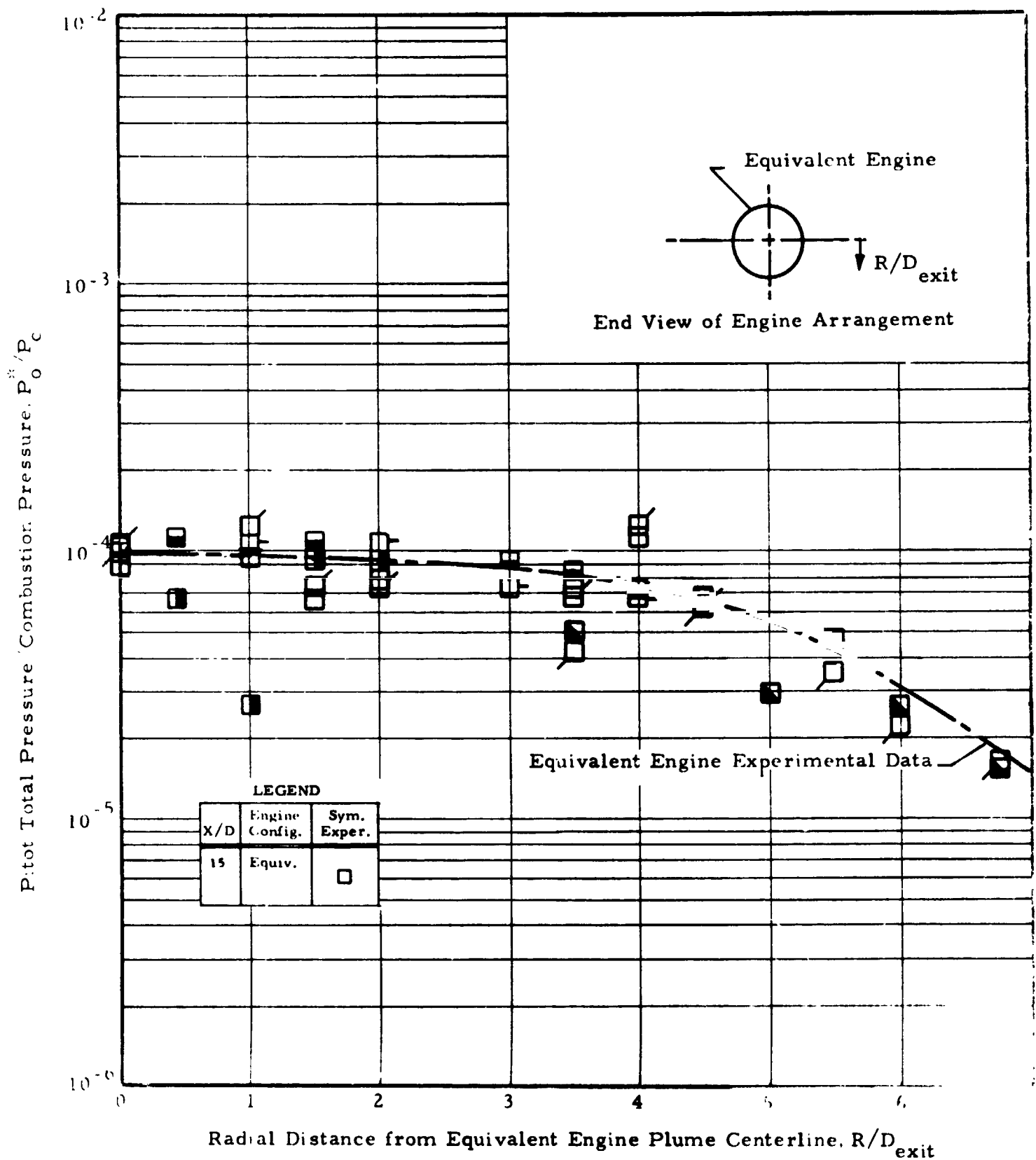


Fig. 26 - Radial Distribution of the Pitot Total Pressure in the Orbiter Main Engine Exhaust Plume at  $X/D = 15$  from the Engine Exit Plane (Equivalent Engine)

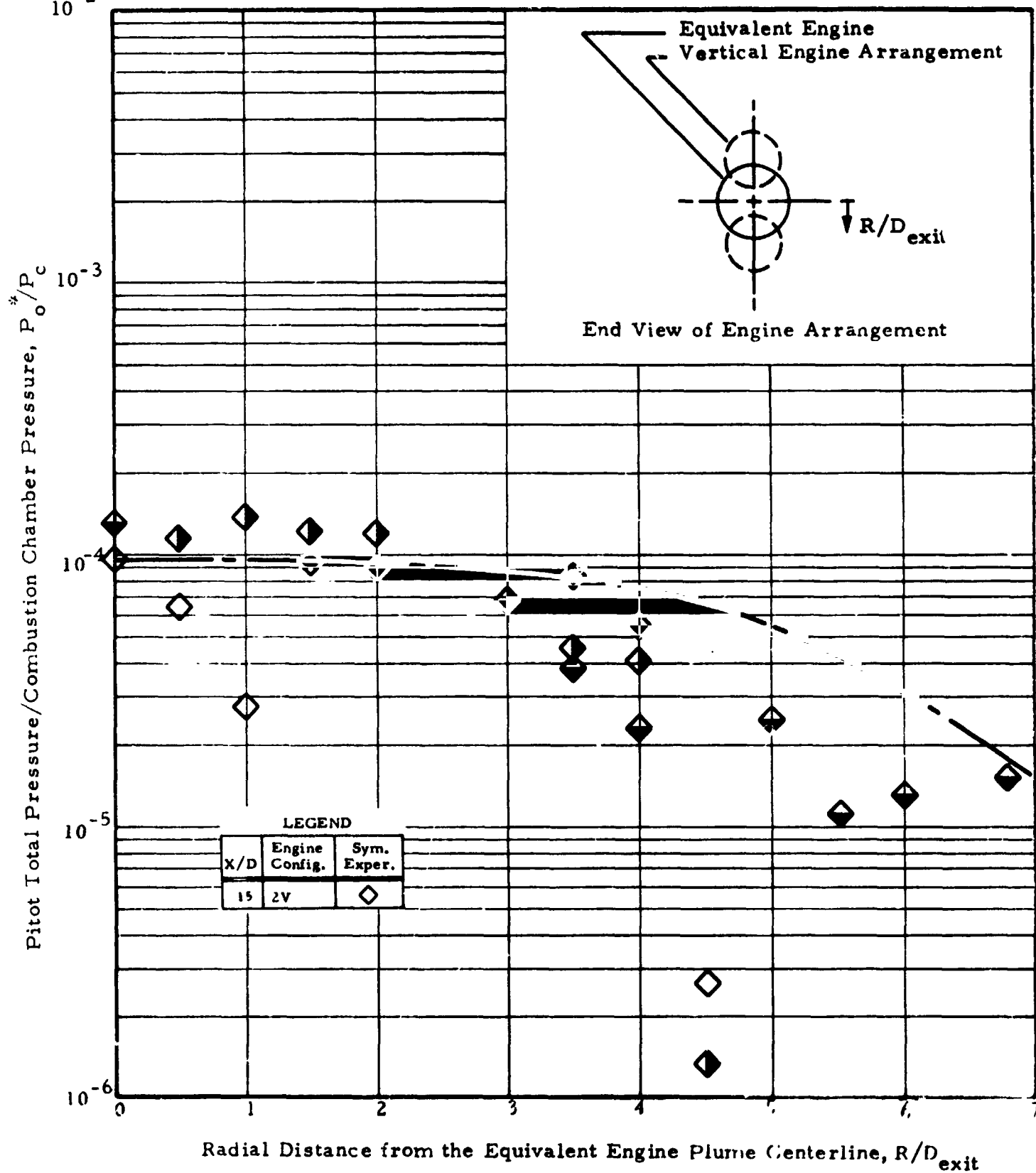


Fig. 27 - Radial Distribution of the Pitot Total Pressure in the Orbiter Main Engine Exhaust Plume at  $X/D = 15$  from the Engine Exit Plane (Vertical Engine Arrangement)

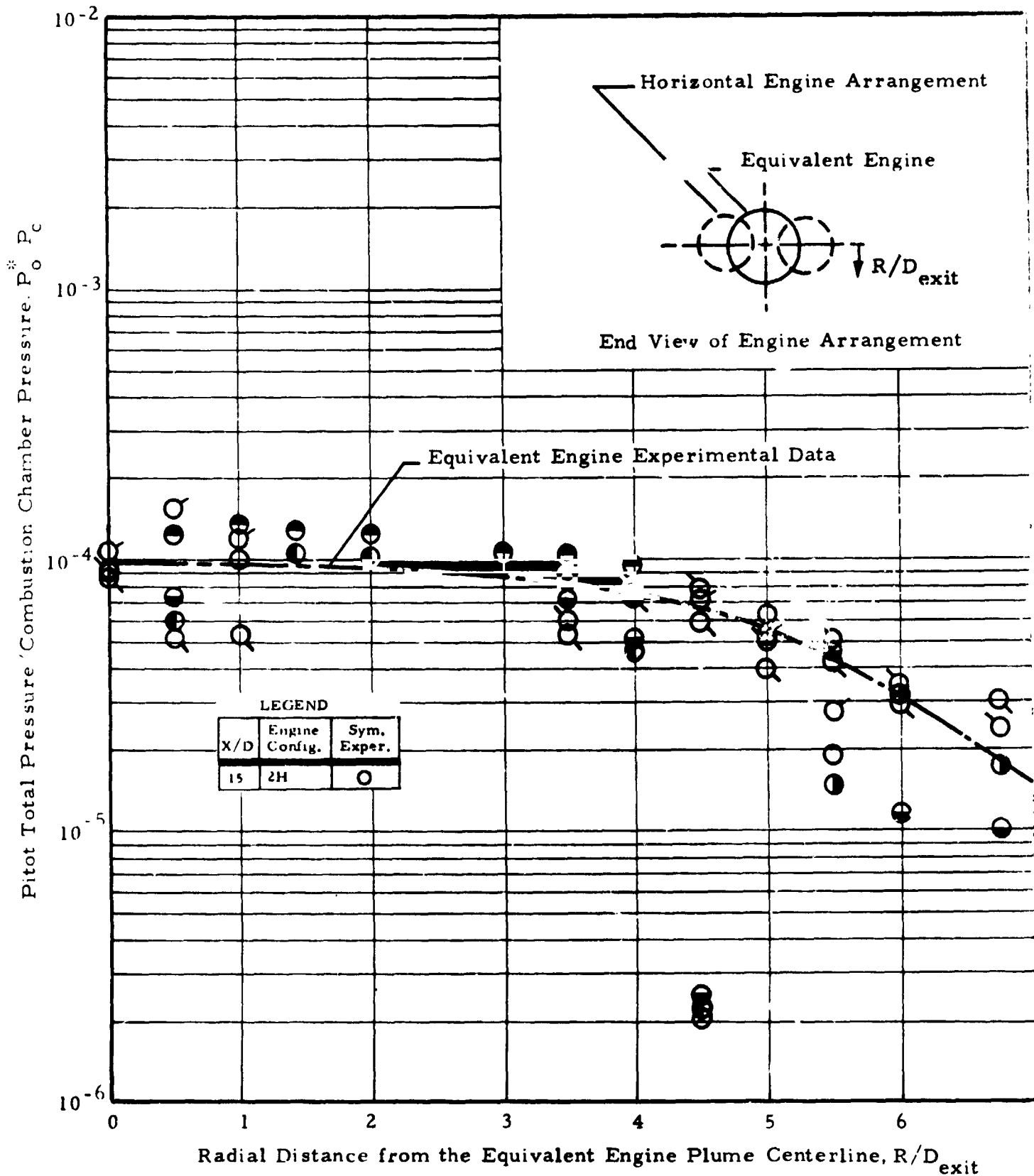


Fig. 28 - Radial Distribution of the Pitot Total Pressure in the Orbiter Main Engine Exhaust Plume at  $X/D = 15$  from the Engine Exit Plane (Horizontal Engine Arrangement)

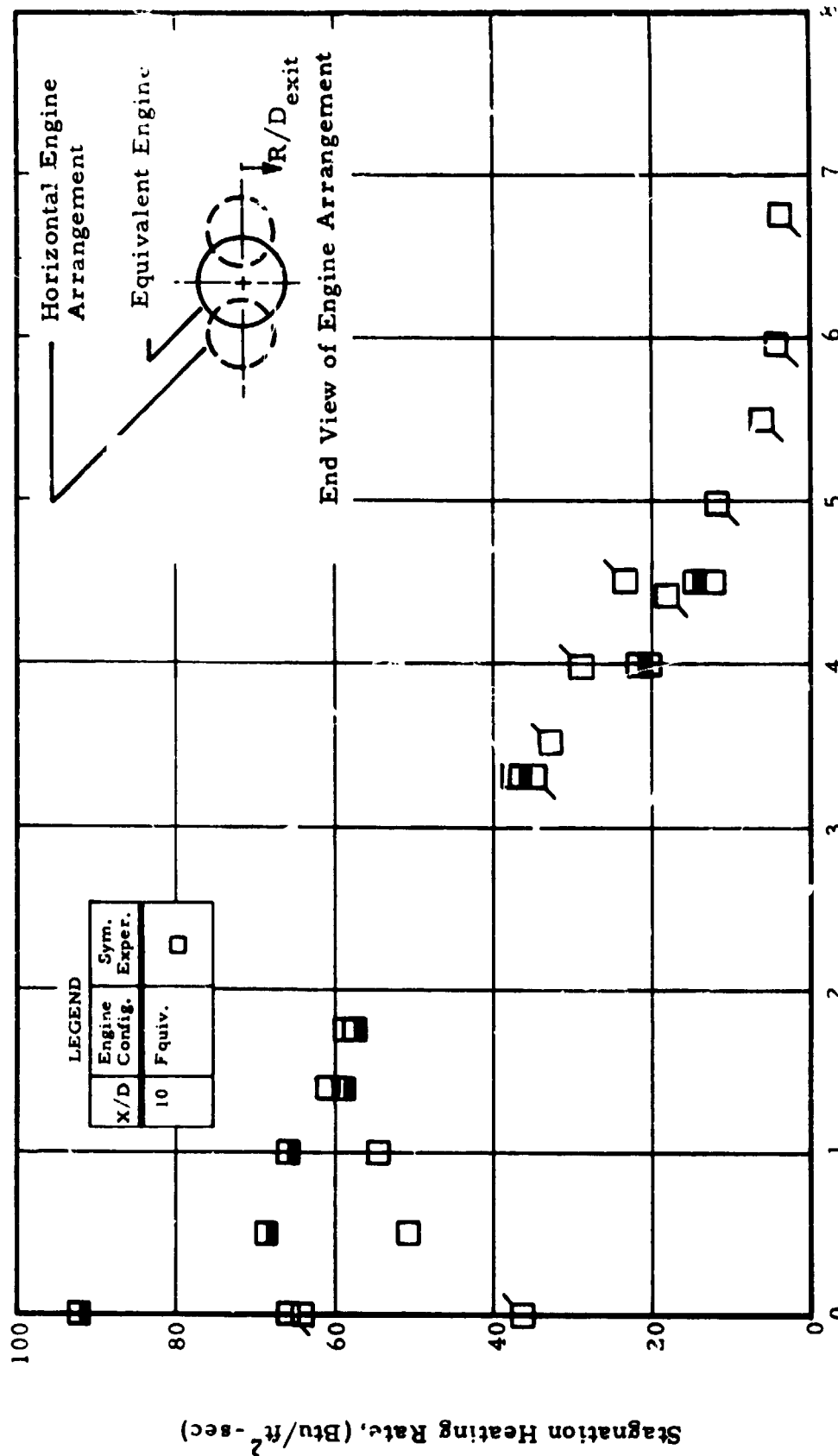


Fig. 29 - Radial Distribution of the Plume Stagnation Heating Rates in the Orbiter Main Engine Exhaust Plume at X/D = 10 from the Engine Exit Plane (Equivalent Engine)

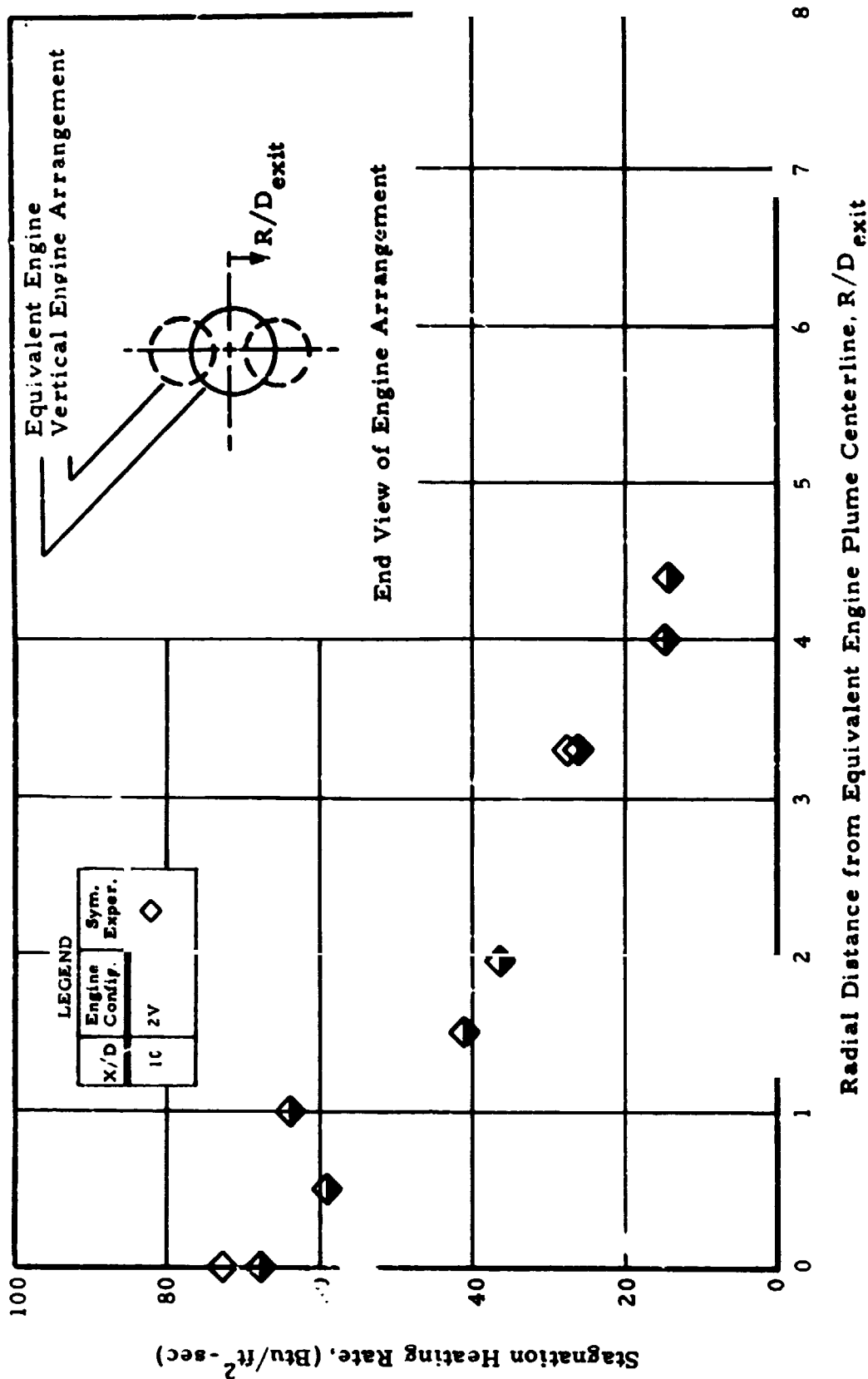
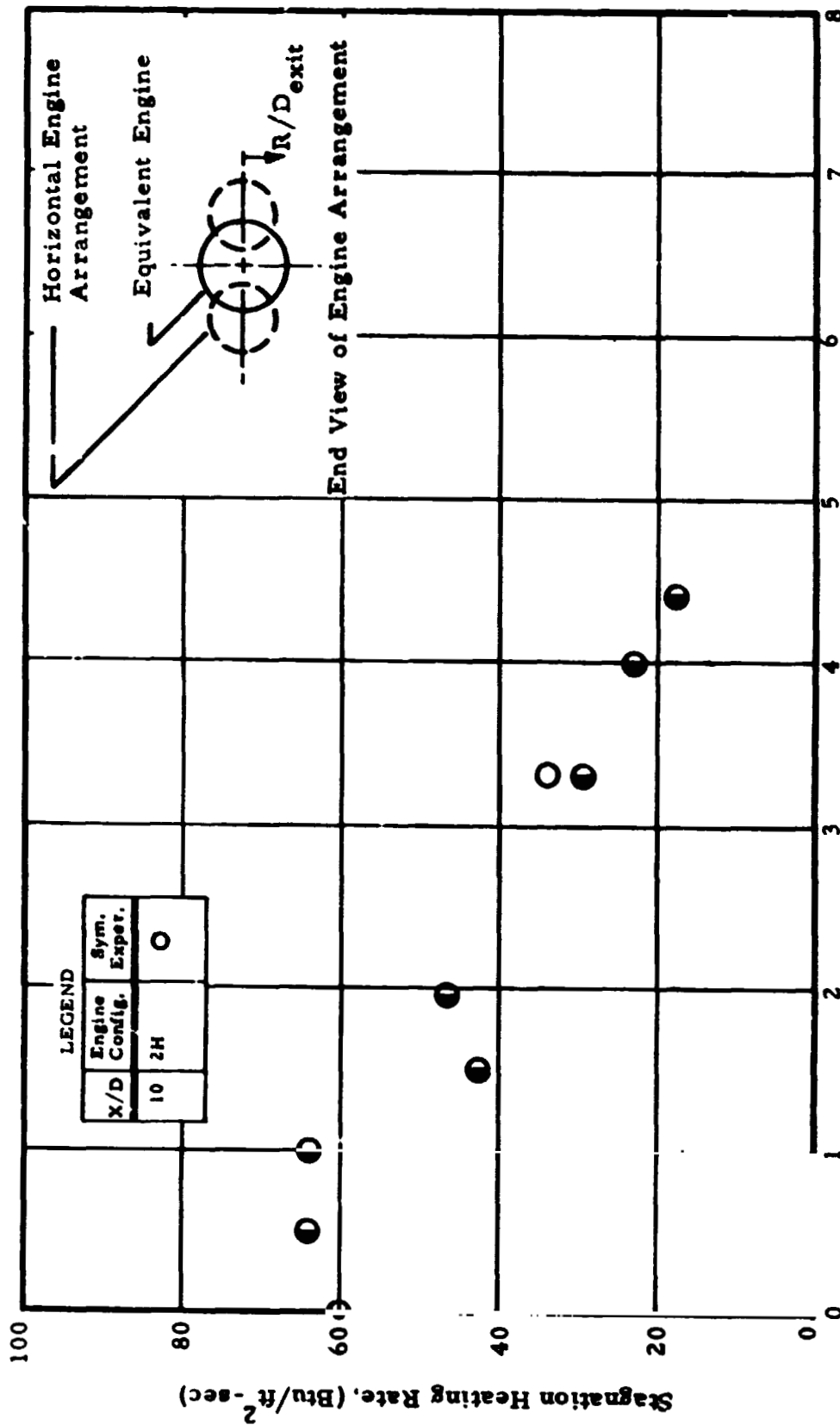


Fig. 30 - Radial Distribution of the Plume Stagnation Heating Rates in the Orbiter Main Engine Exhaust Plume at  $X/D = 10$  from the Engine Exit Plane (Vertical Engine Arrangement)



Radial Distance from Equivalent Engine Plume Centerline, R/D<sub>exit</sub>

Fig. 31 - Radial Distribution of the Plume Stagnation Heating Rate in the Orbiter Main Engine Exhaust Plume at X/D = 10 from the Engine Exit Plane (Horizontal Engine Arrangement)

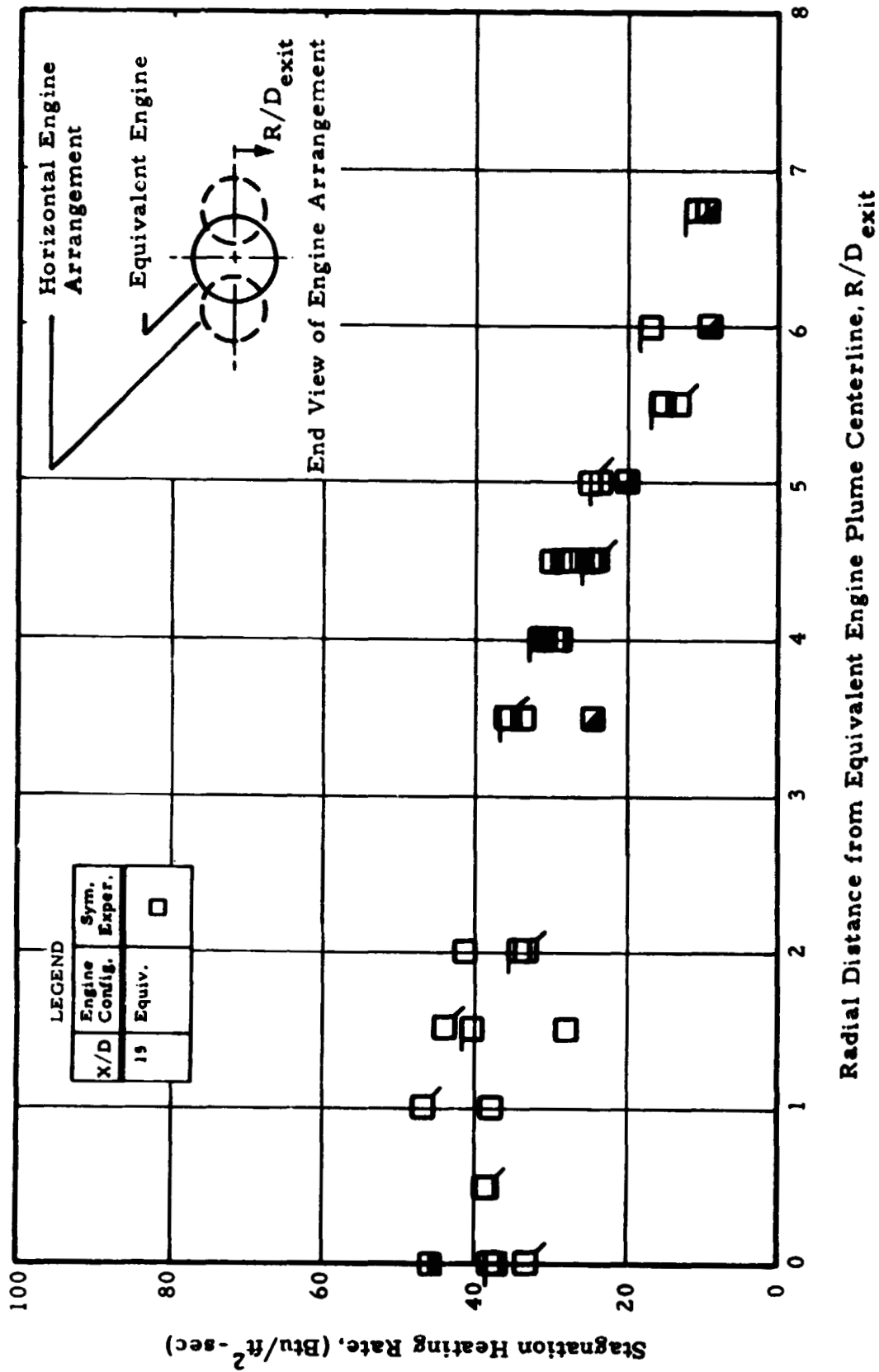


Fig. 32 - Radial Distribution of the Plume Stagnation Heating Rates in the Orbiter Main Engine Exhaust Plume at X/D = 15 from the Engine Exit Plane (Equivalent Engine)

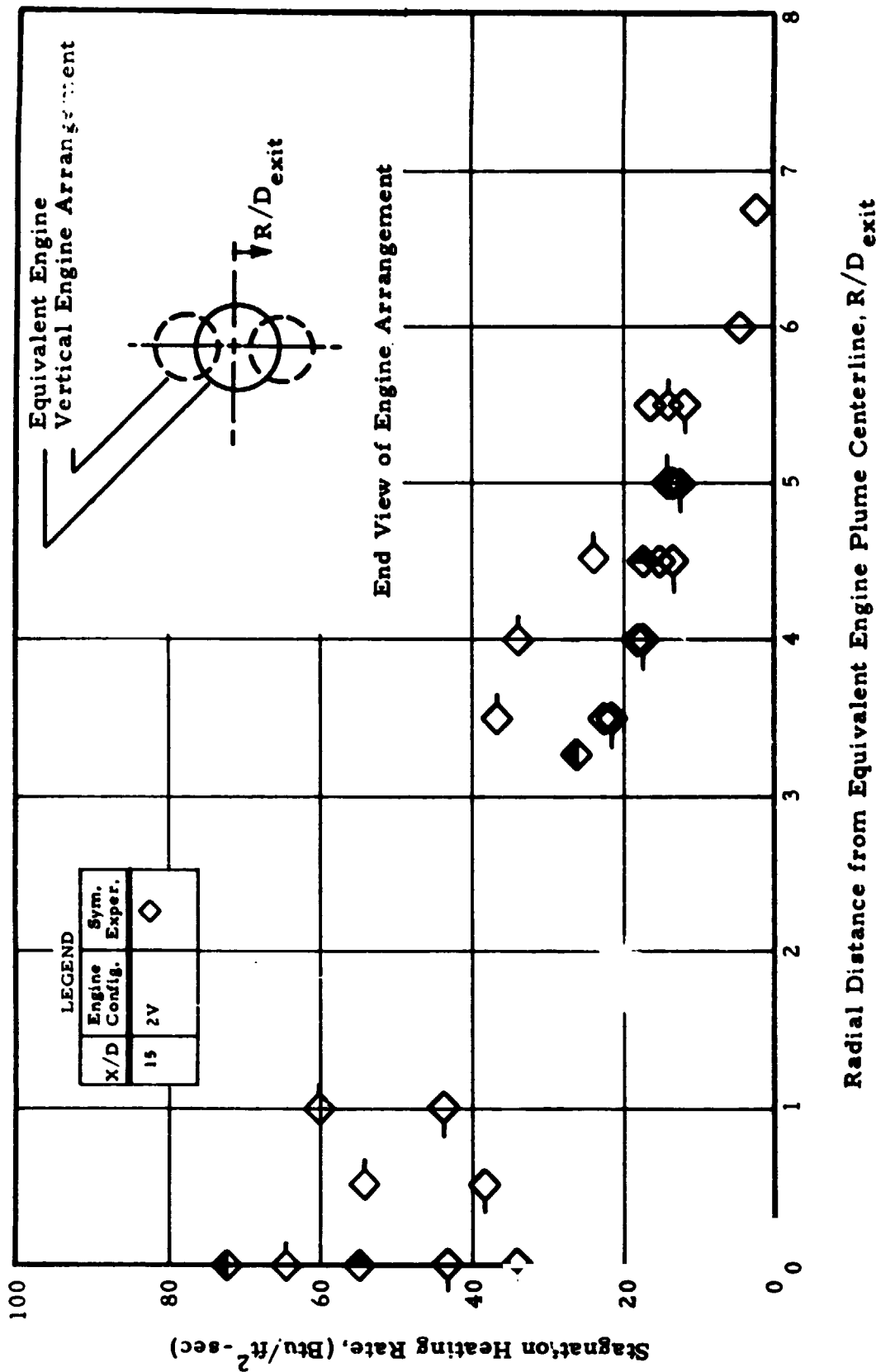


Fig. 33 - Radial Distribution of the Plume Stagnation Heating Rates in the Orbiter Main Engine Exhaust Plume at X/D = 15 from the Engine Exit Plane (Vertical Engine Arrangement)

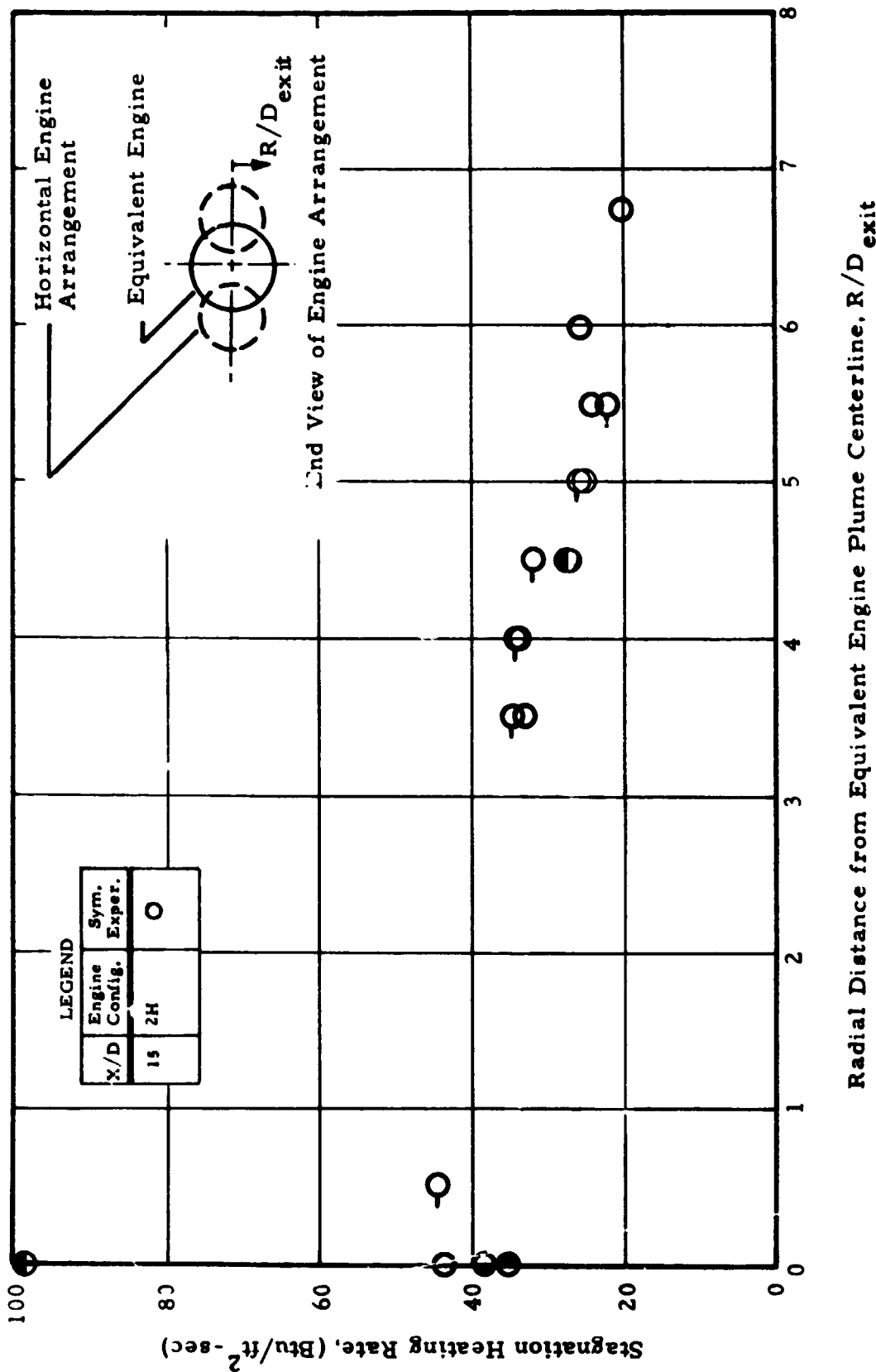


Fig. 34 - Radial Distribution of the Plume Stagnation Heating Rates in the Orbiter Main Engine Exhaust Plume at X/D = 15 from the Engine Exit Plane (Horizontal Engine Arrangement)

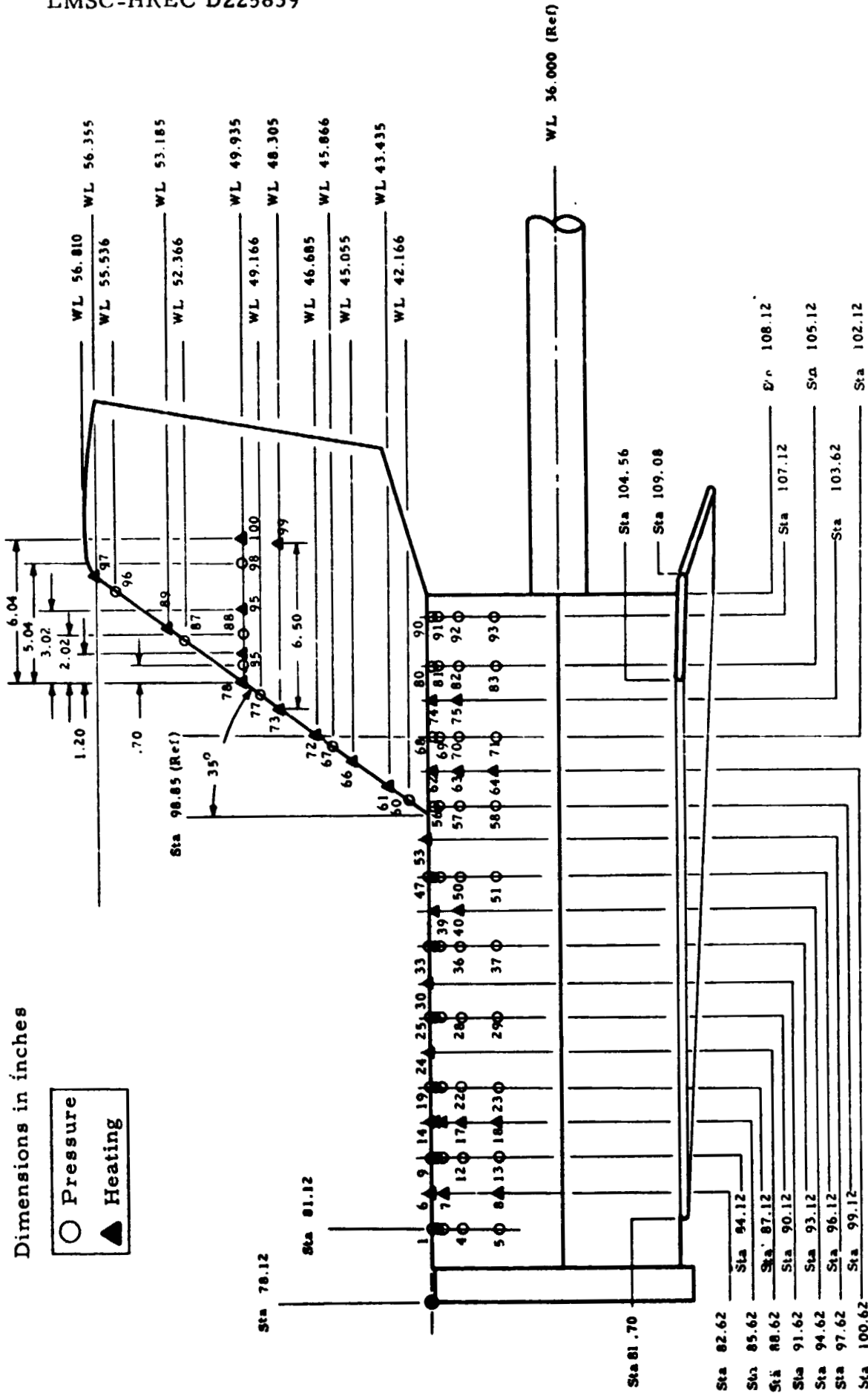


Fig. 35 - Model Instrumentation Locations - Side View

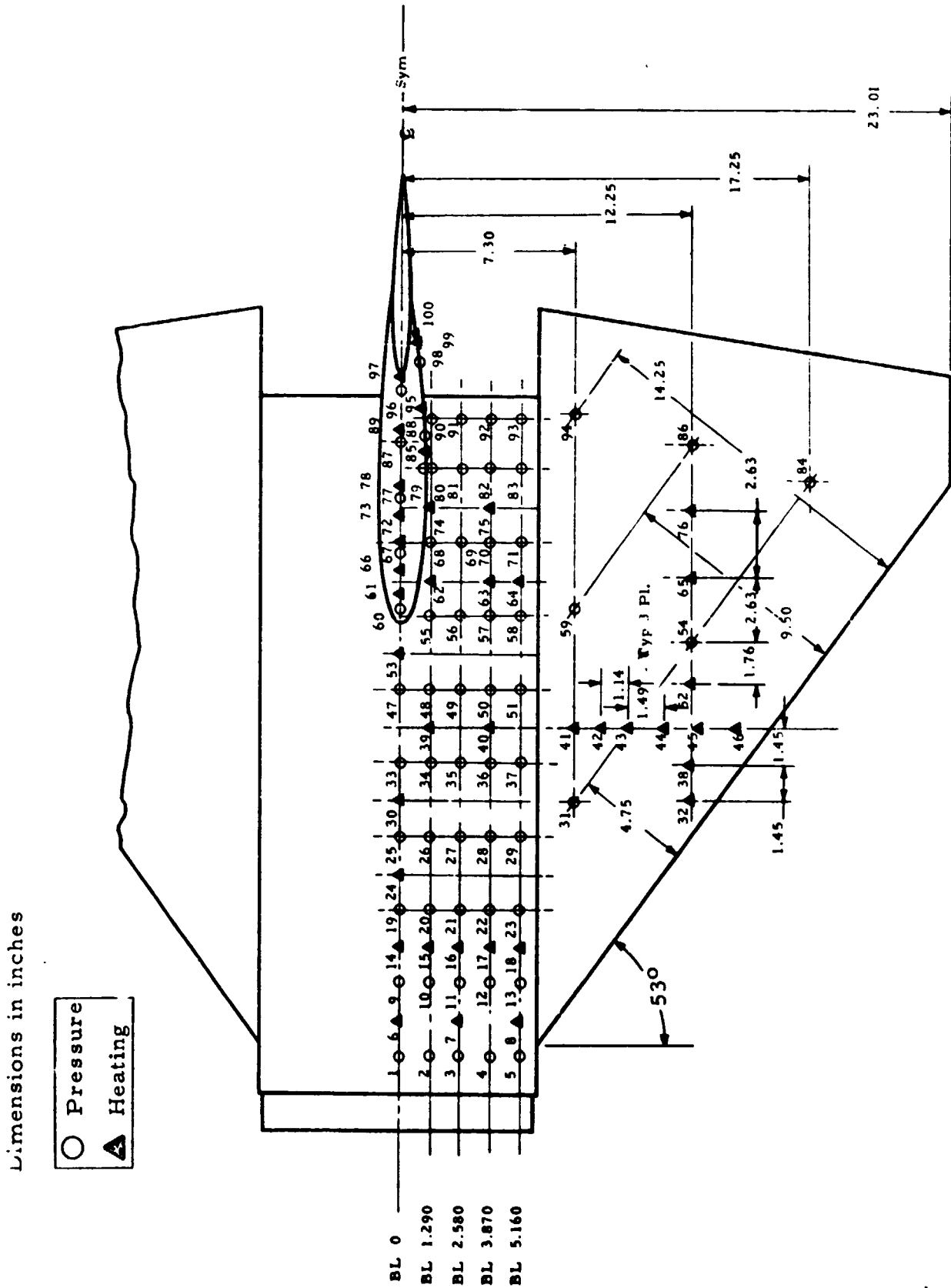


Fig.36 - Model Instrumentation Locations -- Top View

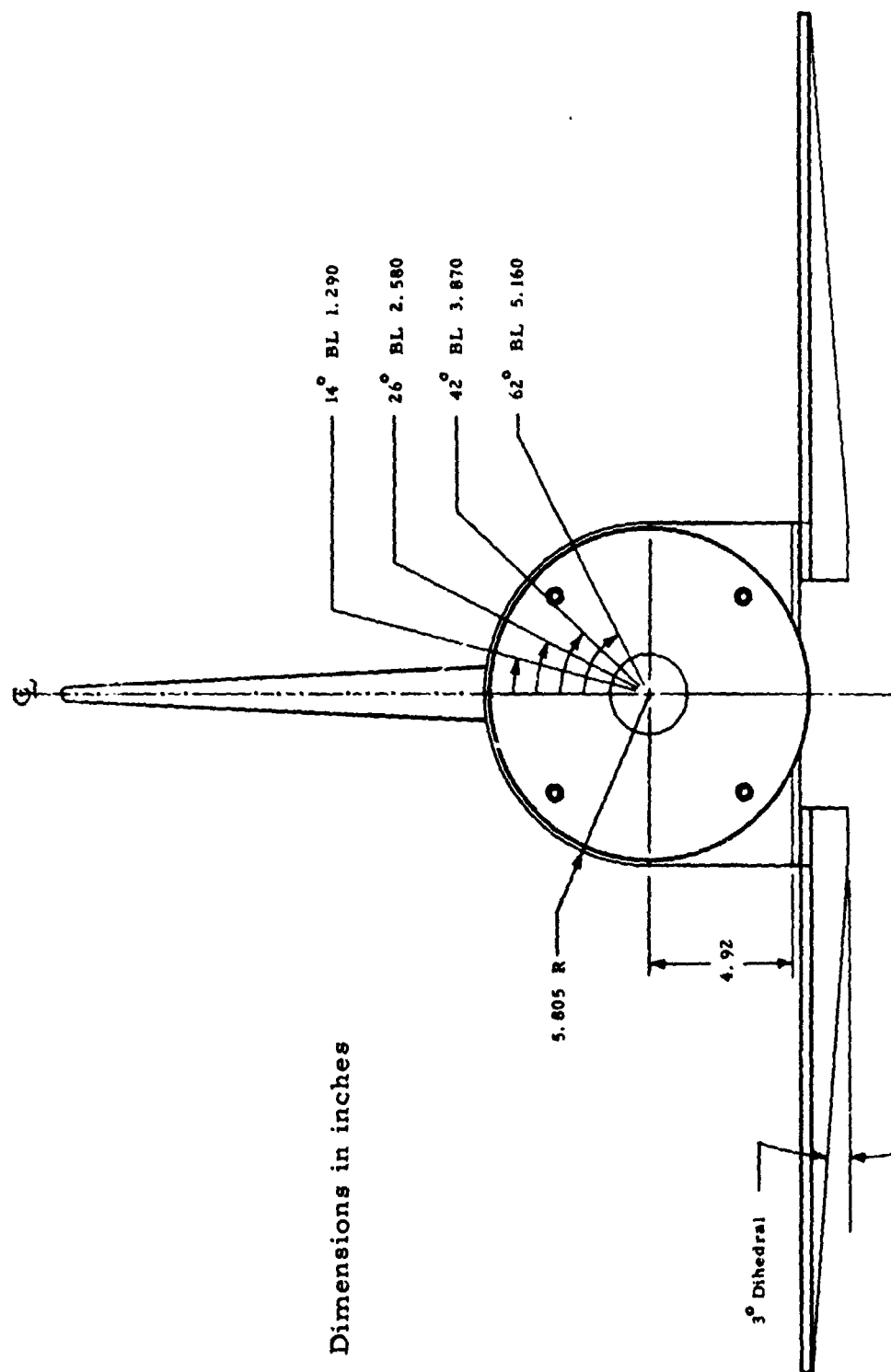


Fig. 37 - Model Instrumentation Locations - Front View

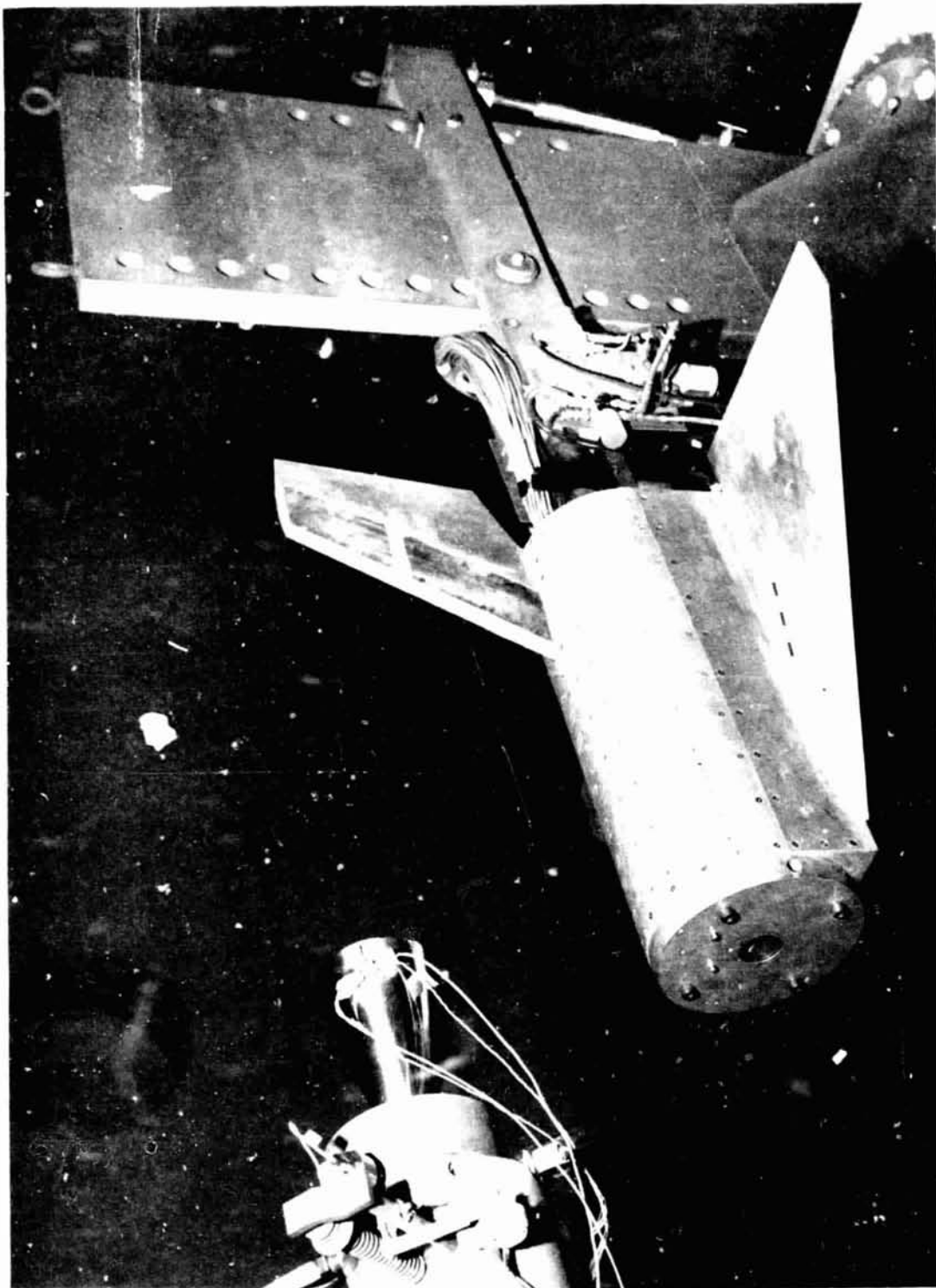


Fig. 38 - Model and Equivalent Engine Configuration

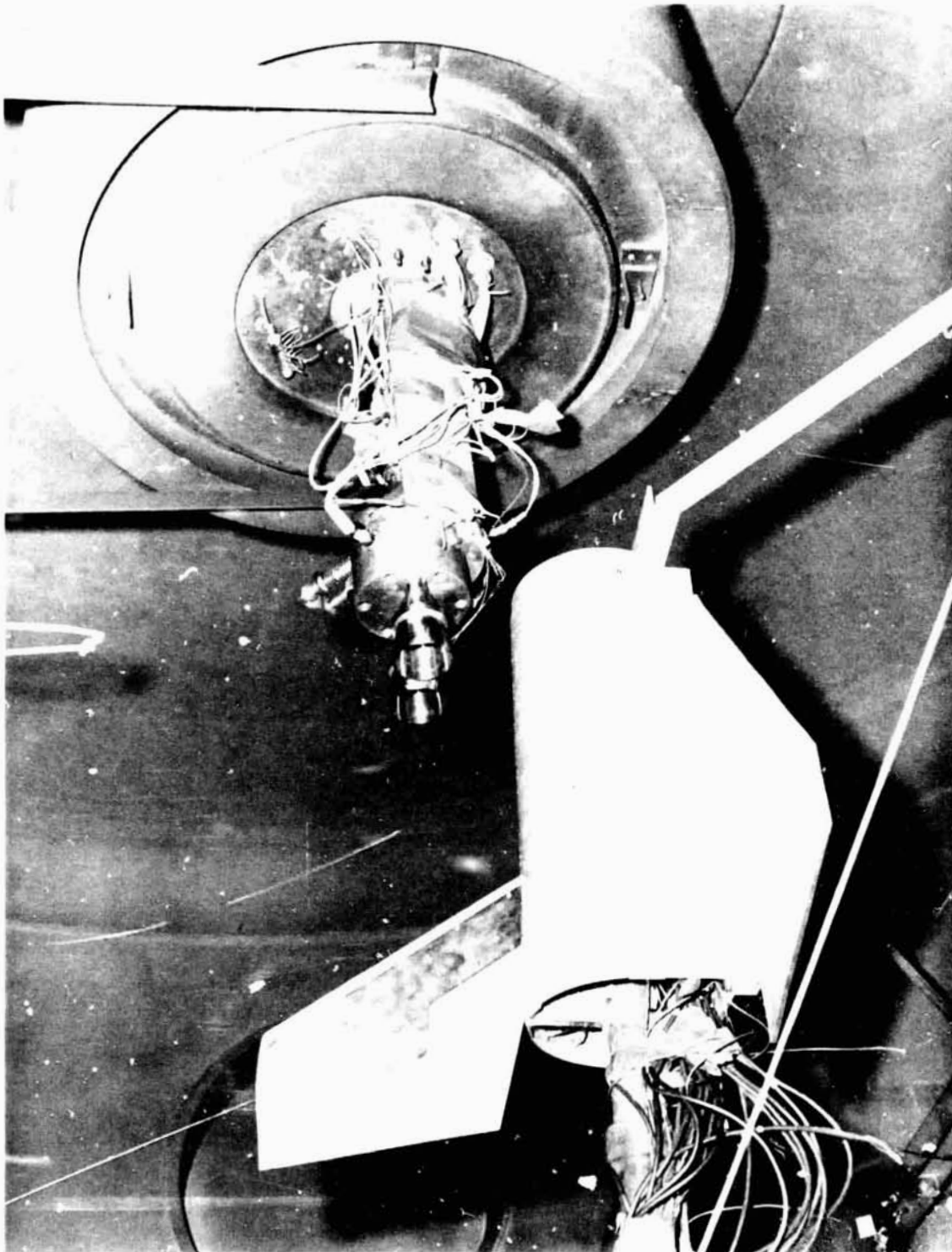


Fig. 39 - Model and Dual Horizontal Engine Configuration

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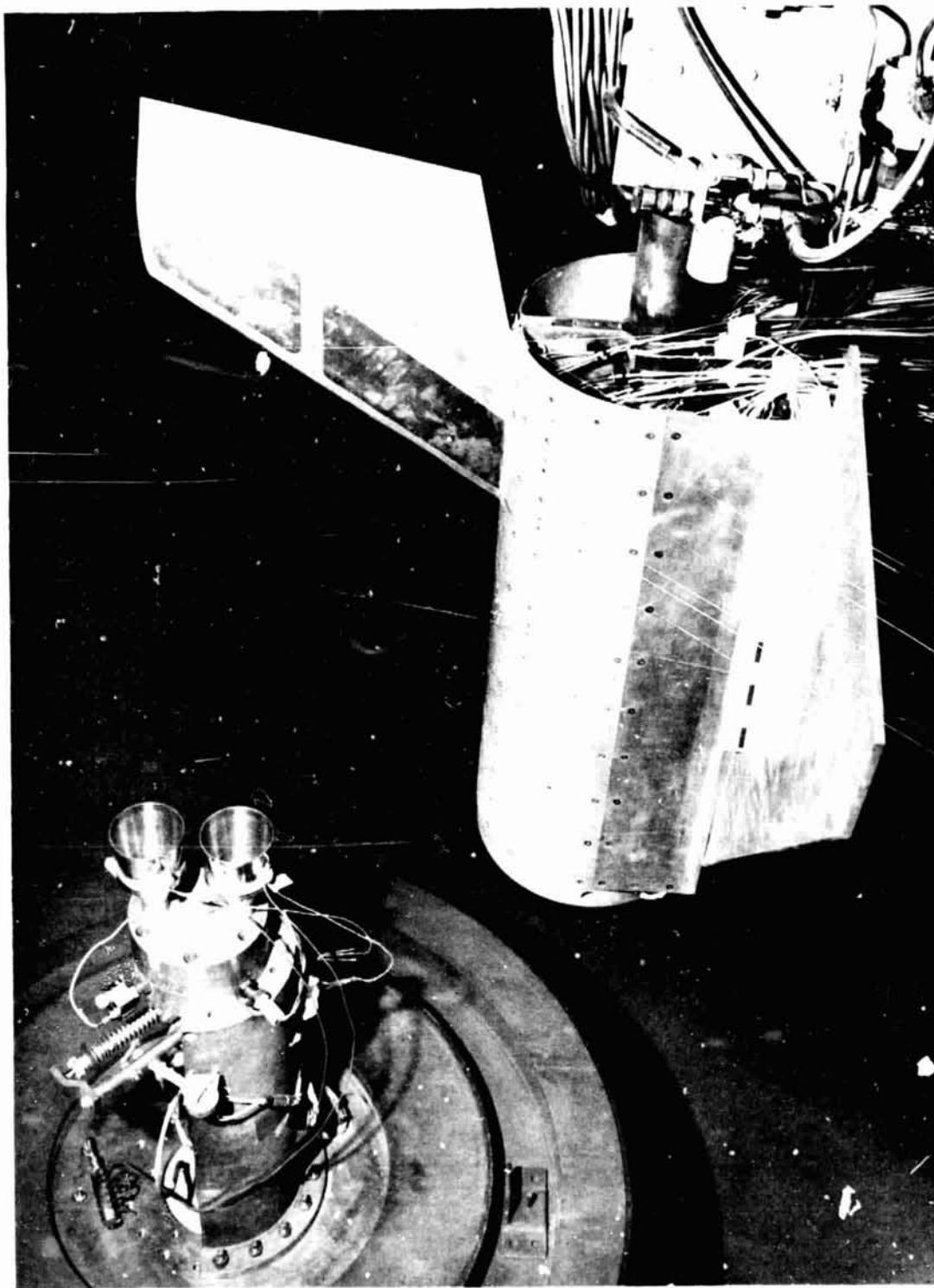


Fig. 40 - Model and Dual Vertical Engine Configuration

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NOTE:  $\alpha$  = inclination of orbiter engine centerline with respect to the booster fuselage centerline

$D_{equiv}$  = exit diameter of the equivalent engine, 5.286 in.

Test Pos.	x (in.)	y (in.)	$\frac{x}{D_{equiv}}$	$\frac{y}{D_{equiv}}$	$\alpha$ (deg)
2	-3.297	4.644	-0.624	.878	0
4	-18.390	6.966	-3.479	1.318	0
5	-6.780	6.966	-1.283	1.318	0
8	-6.780	6.966	-1.283	1.318	5
11	-11.424	14.513	-2.161	2.746	4
14	-11.424	14.513	-2.161	2.746	0
15	0.186	14.513	0.035	2.746	0
17	-6.780	23.22	-1.283	4.393	0
29	-6.780	23.22	-1.283	4.393	5
30	-1.180	23.22	-0.223	4.393	0
31	-8.424	14.513	-1.594	2.746	0

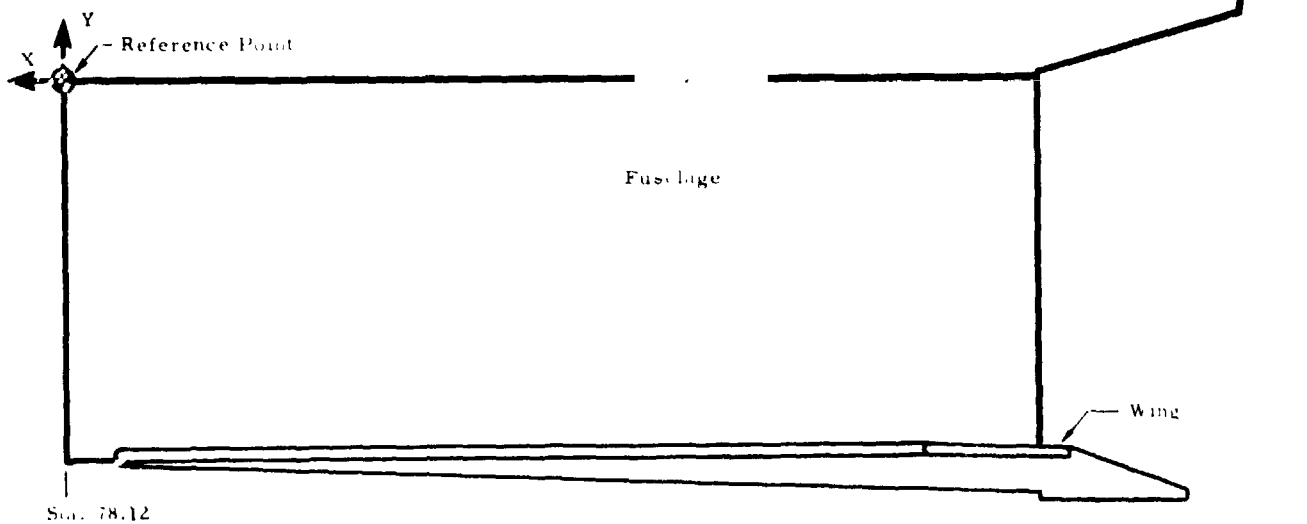
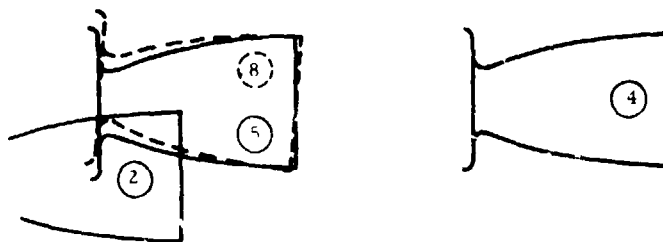
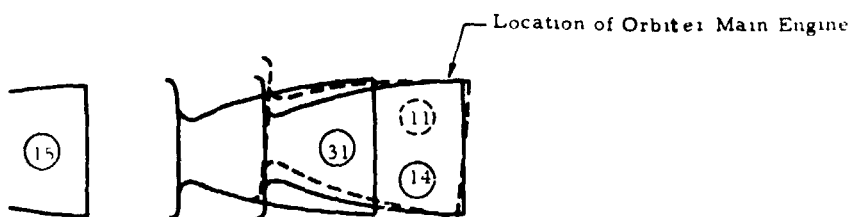
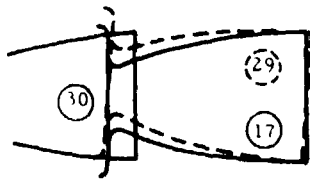
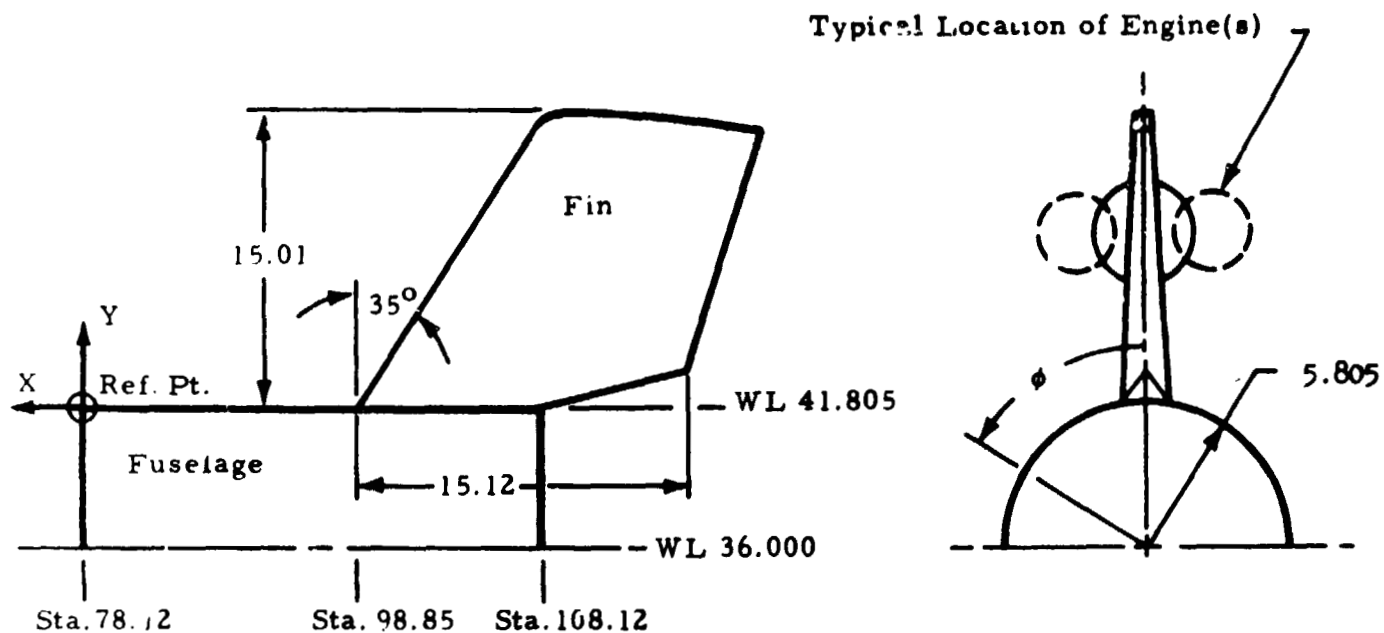
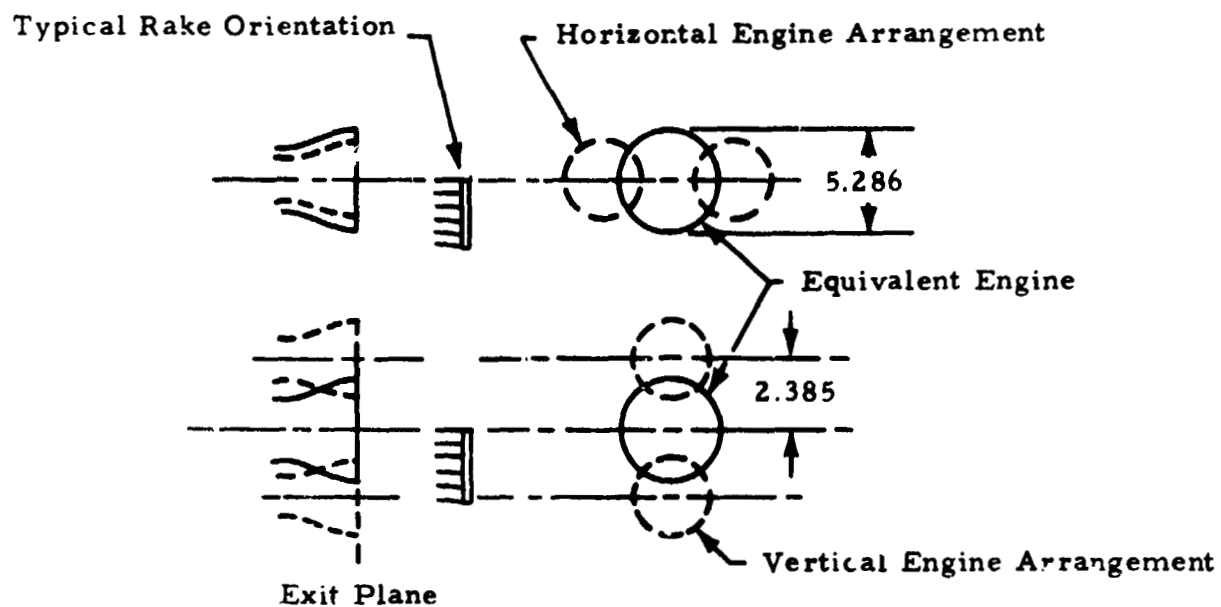


Fig. 41 - Engine/Booster Relative Test Positions

**NOTE: All dimensions in inches**



### Sketch of Booster Geometry



### Sketch of Engine Arrangement

Fig. 42 - Sketc' of Model Geometry and Engine Arrangement

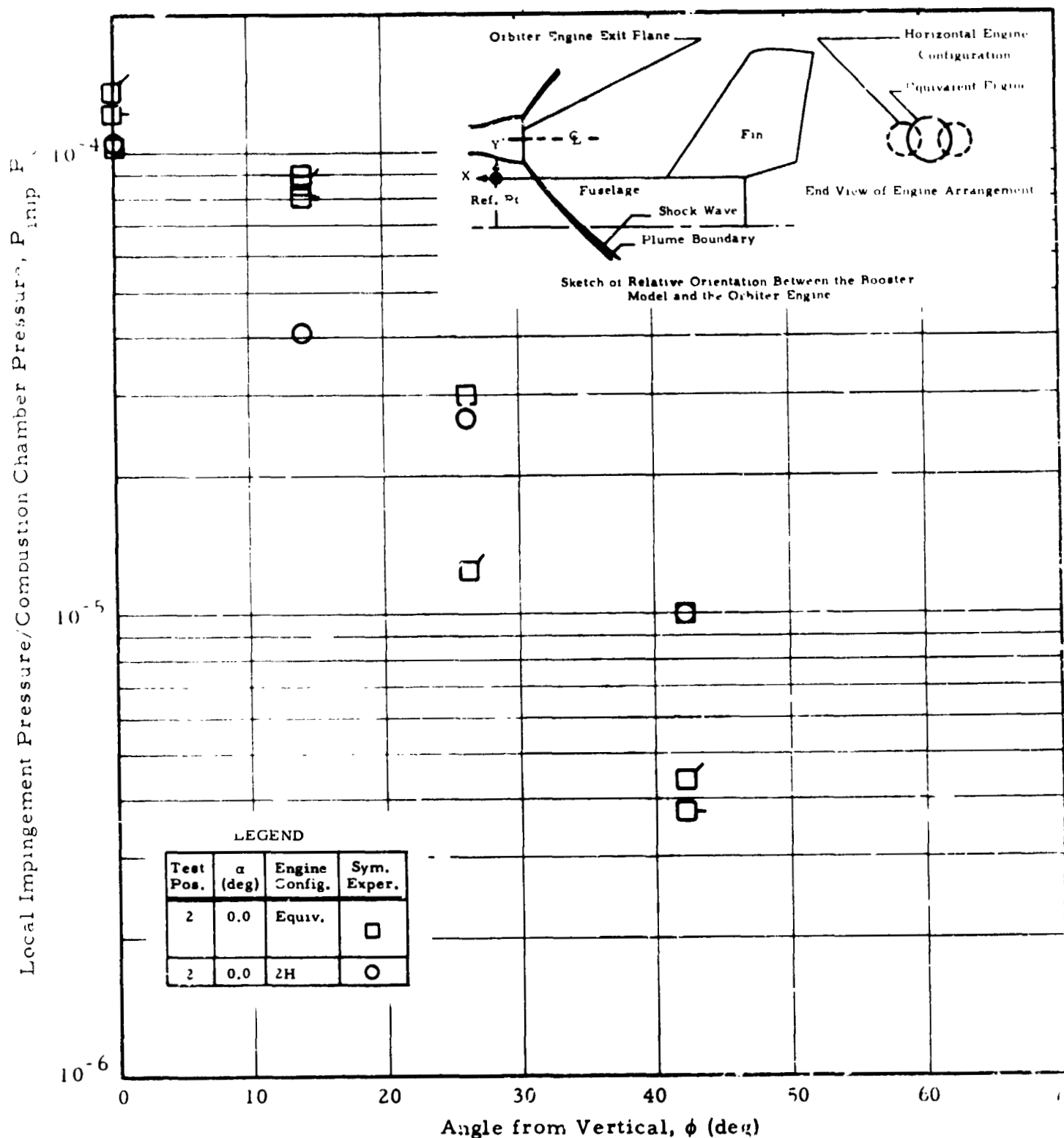


Fig. 43 - Impingement Pressure Distribution over the Booster Fuselage at Station 87.12 (Test Pos. 2)

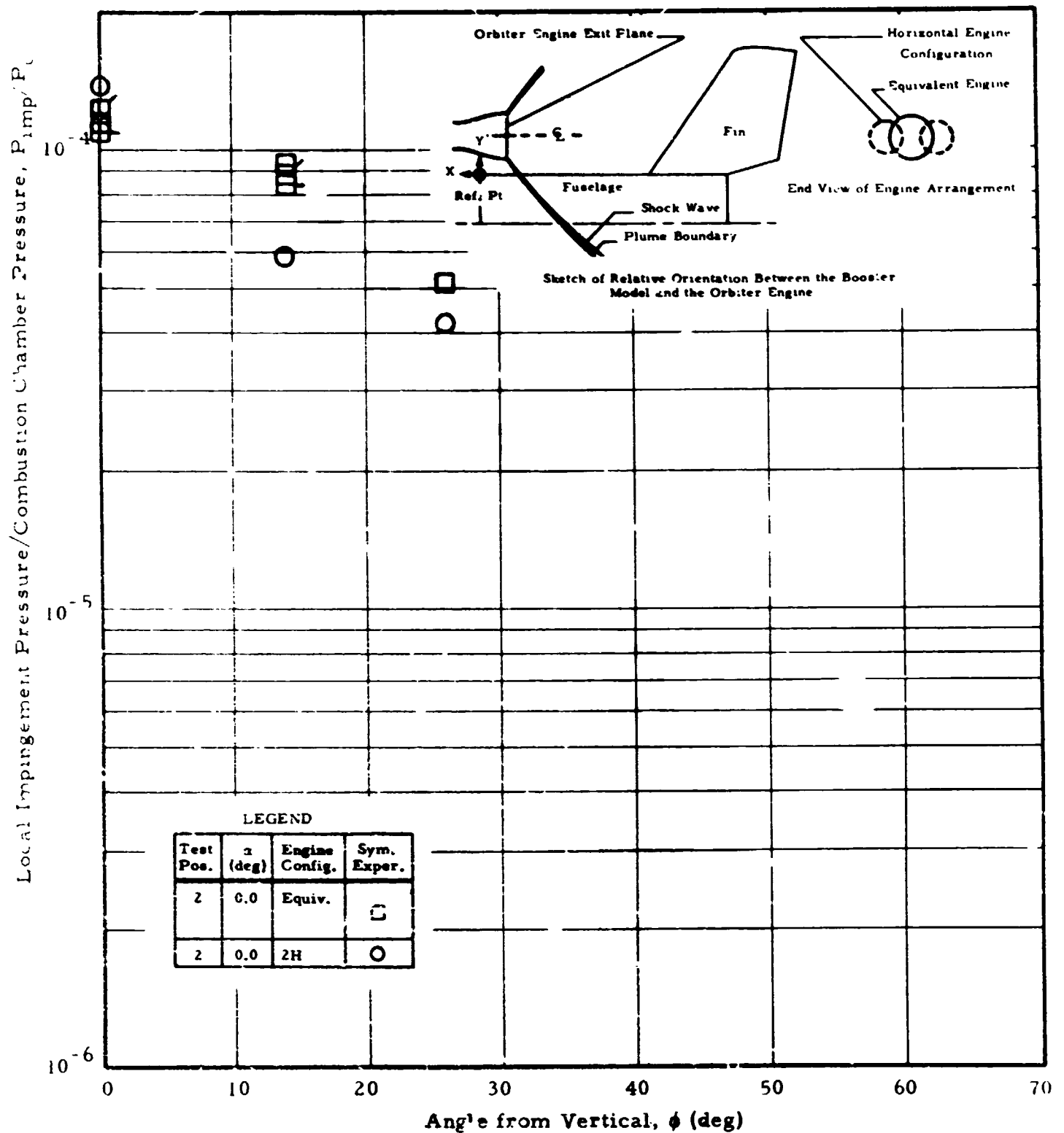


Fig. 44 - Impingement Pressure Distribution over the Booster Fuselage at Station 90.12 (Test Pos. 2)

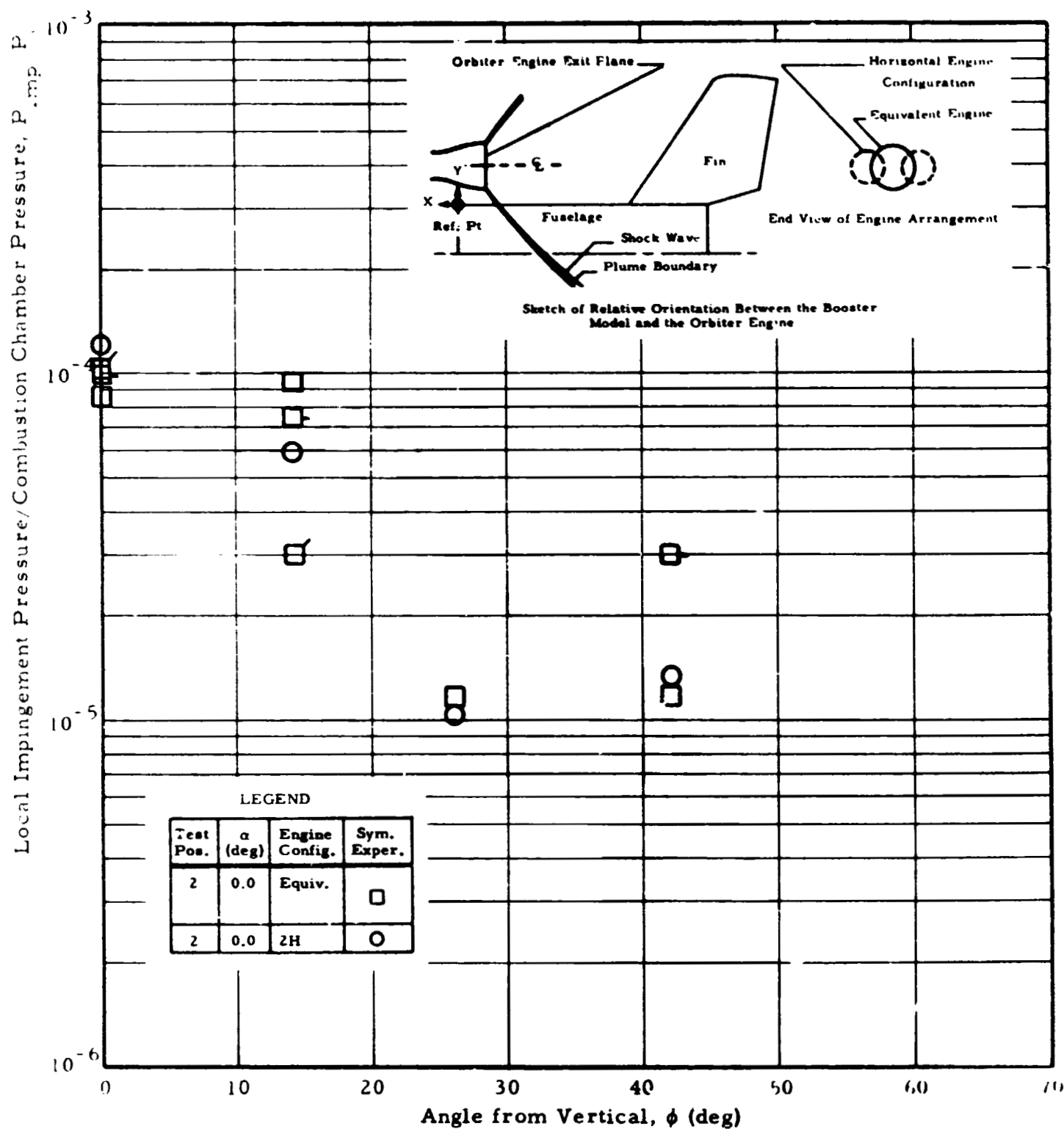


Fig. 45 - Impingement Pressure Distribution over the Booster Fuselage at Station 93.12 (Test Pos. 2)

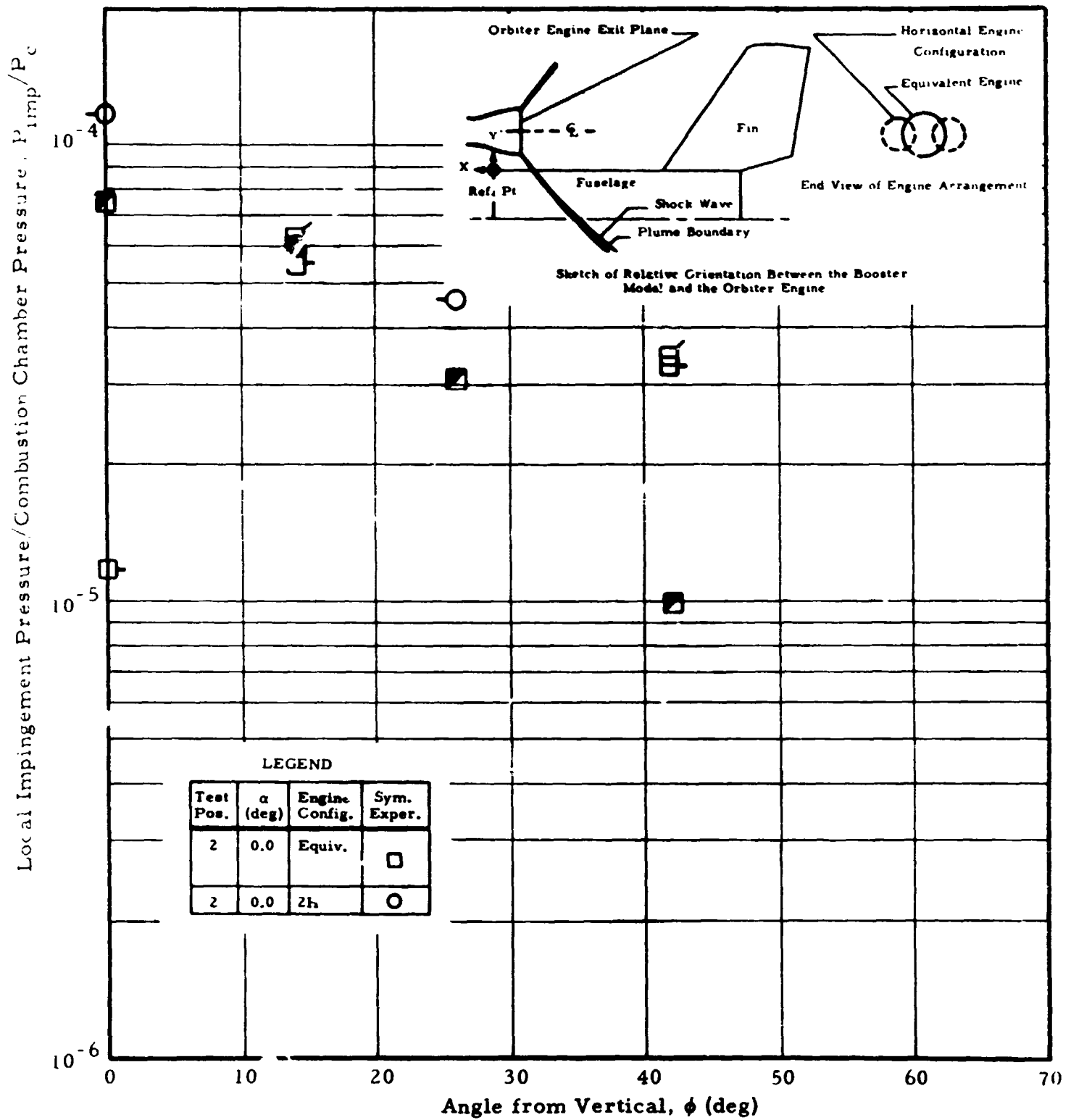


Fig. 46 Impingement Pressure Distribution over the Booster Fuselage at Station 96.12 (Test Pos. 2)

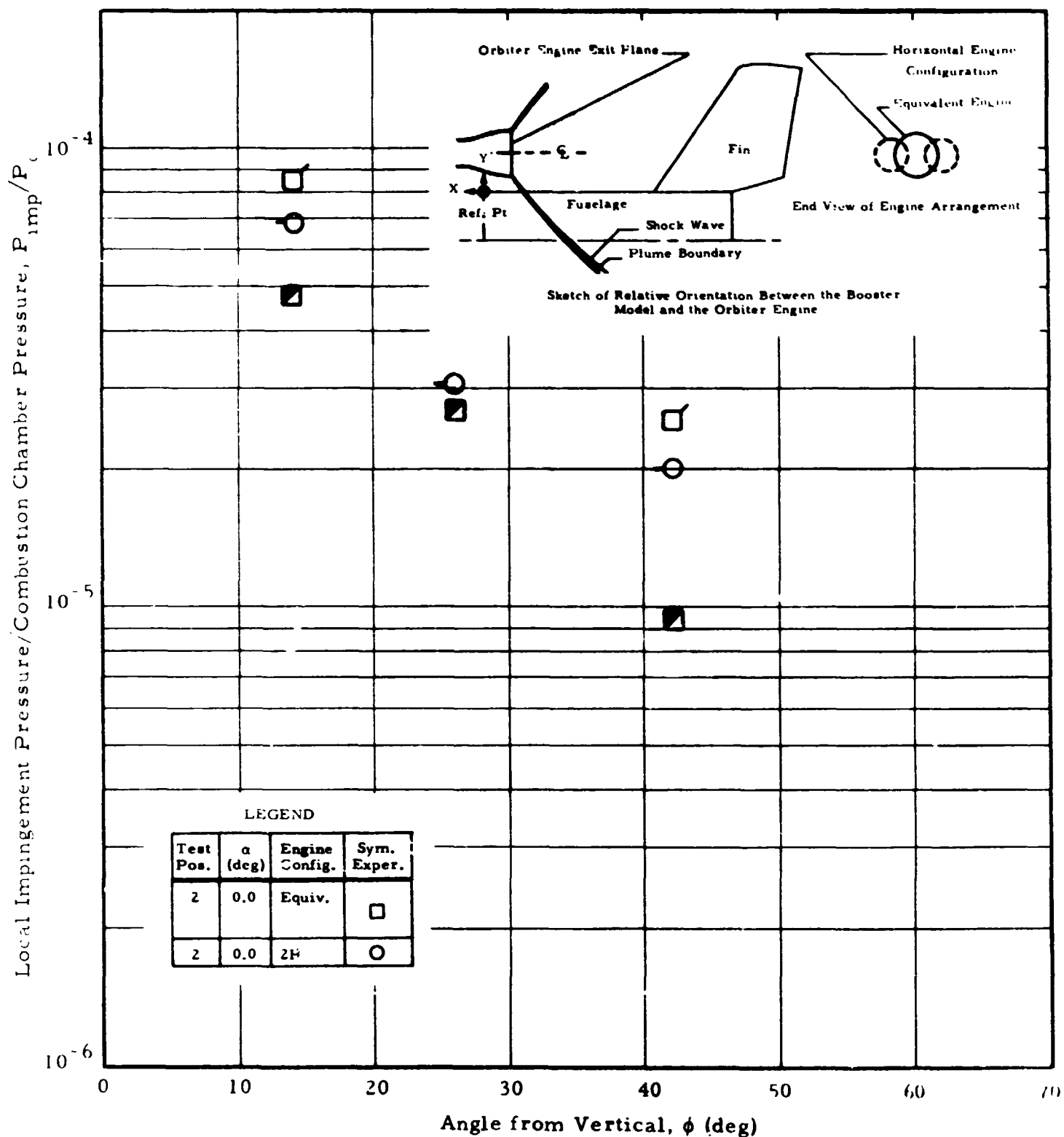


Fig. 47 - Impingement Pressure Distribution over the Booster Fuselage at Station 99.12 (Test Pos. 2)

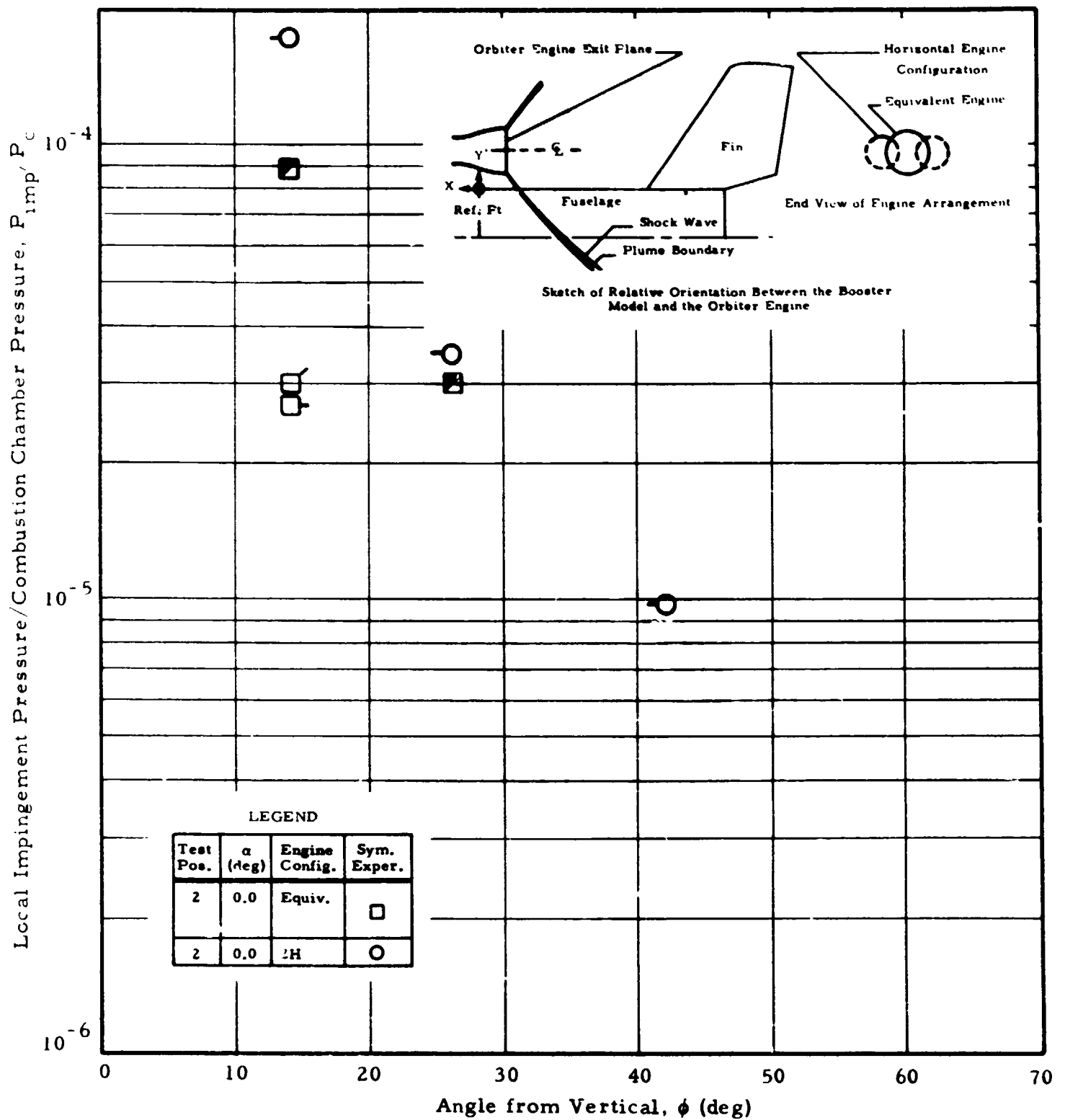


Fig. 48 - Impingement Pressure Distribution over the Booster Fuselage at Station 102.12 (Test Pos. 2)

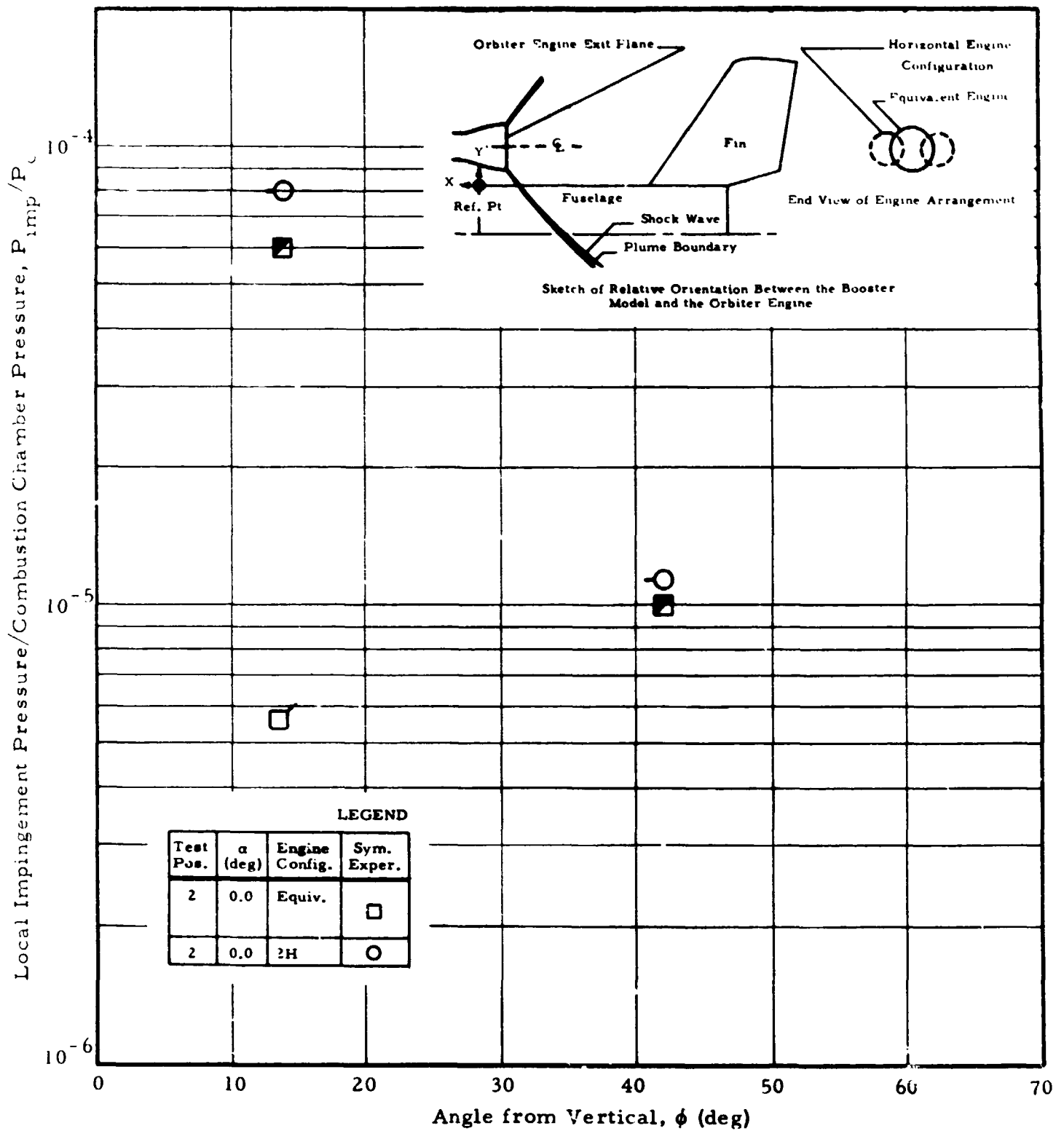


Fig. 49 - Impingement Pressure Distribution over the Booster Fuselage at Station 105.12 (Test Pos. 2)

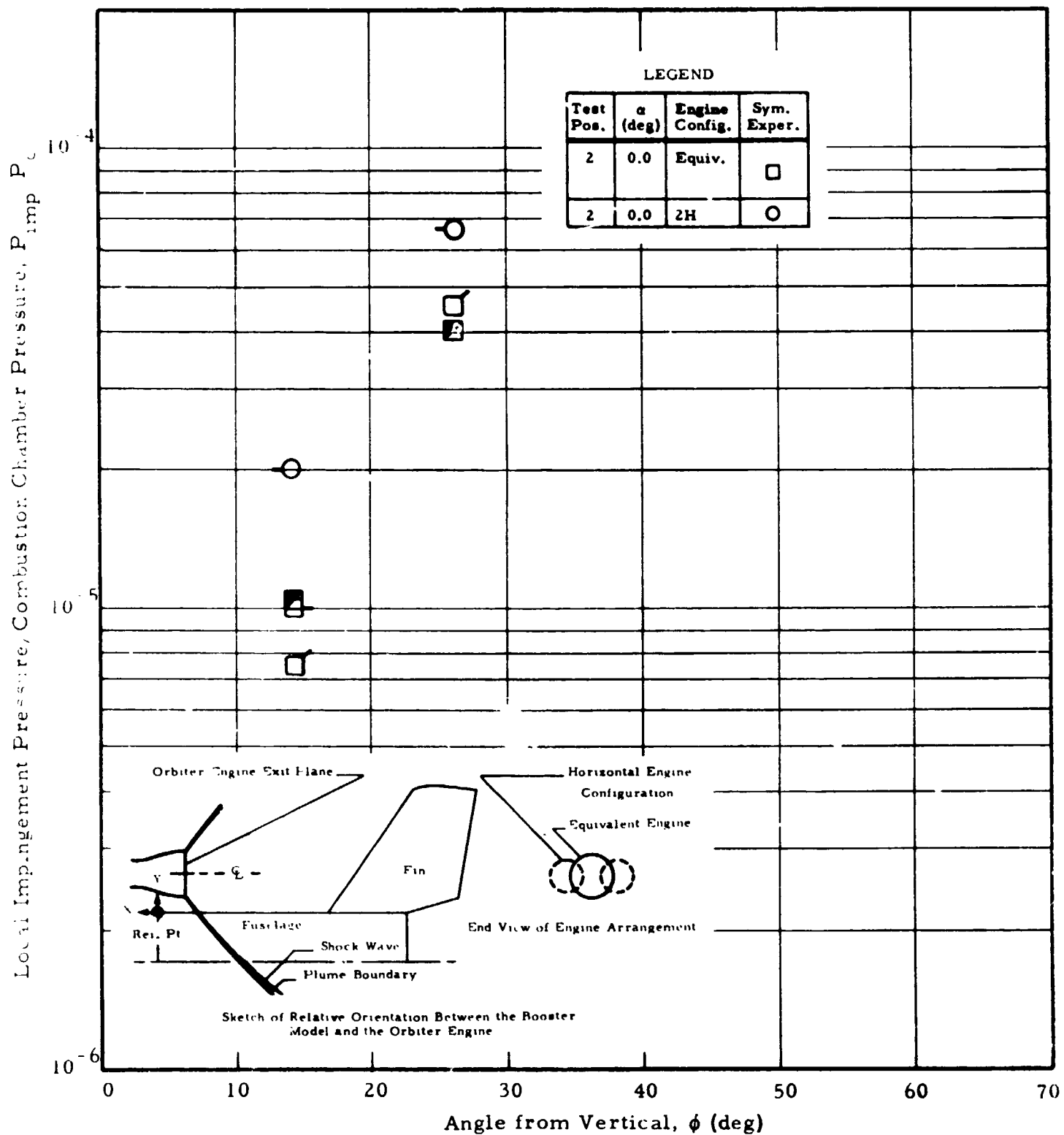


Fig. 50 - Impingement Pressure Distribution over the Booster Fuselage at Station 107.12 (Test Pos. 2)

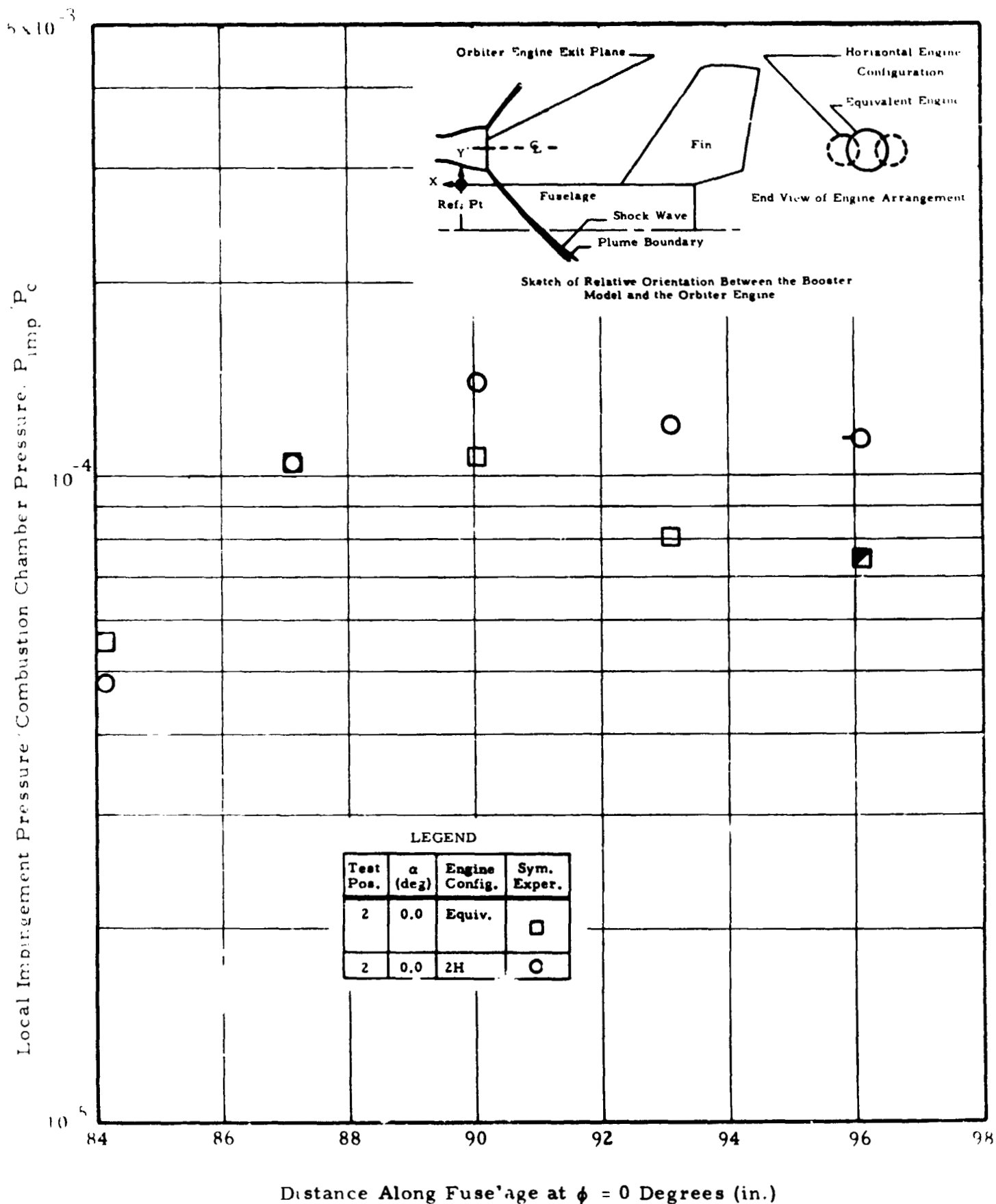


Fig. 51 - Impingement Pressure Distribution Along Fuselage Stagnation Line  
(Test Pos. 2)

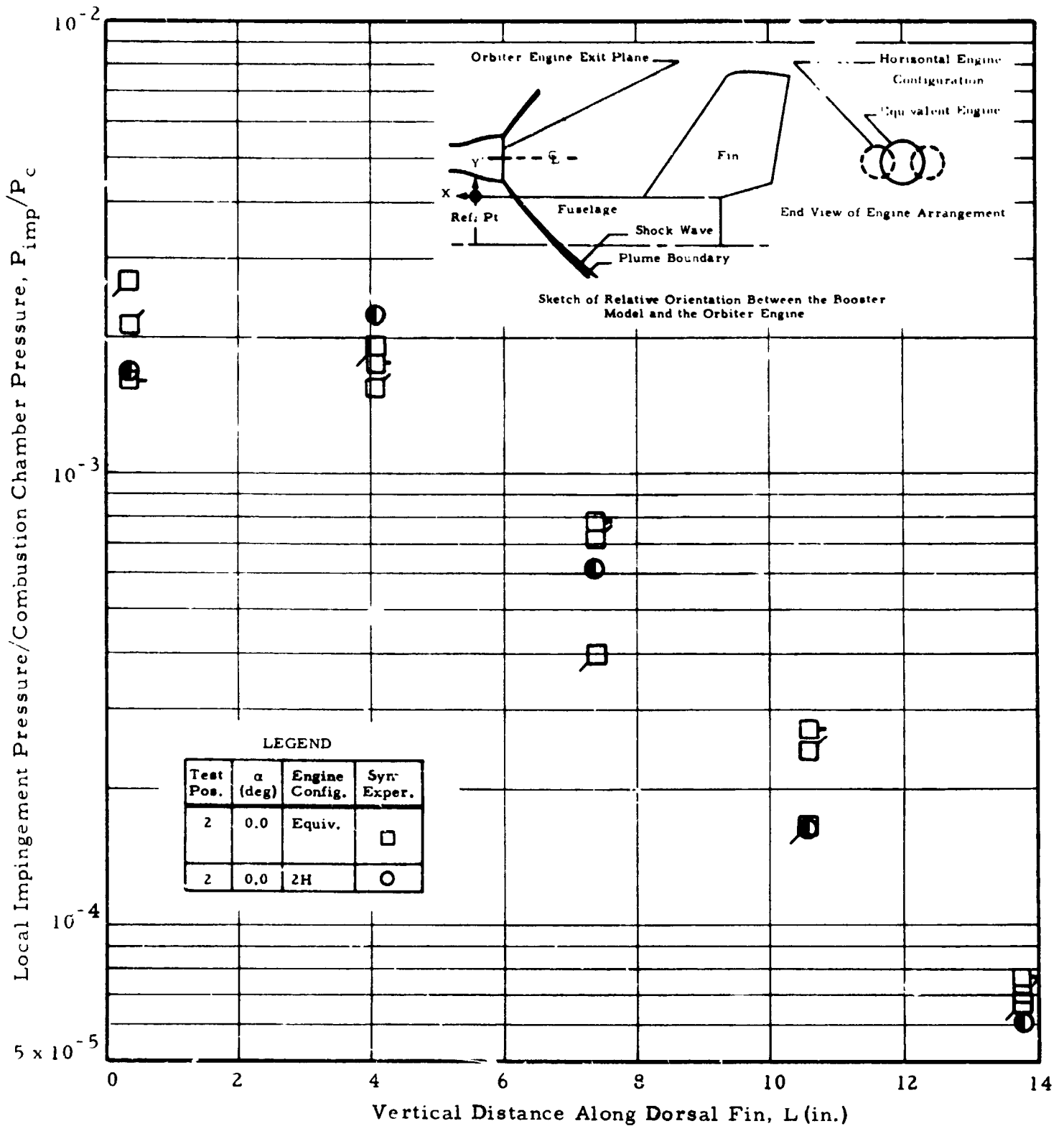


Fig. 52 - Impingement Pressure Distribution Along Dorsal Fin Leading Edge (Test Pos. 2)

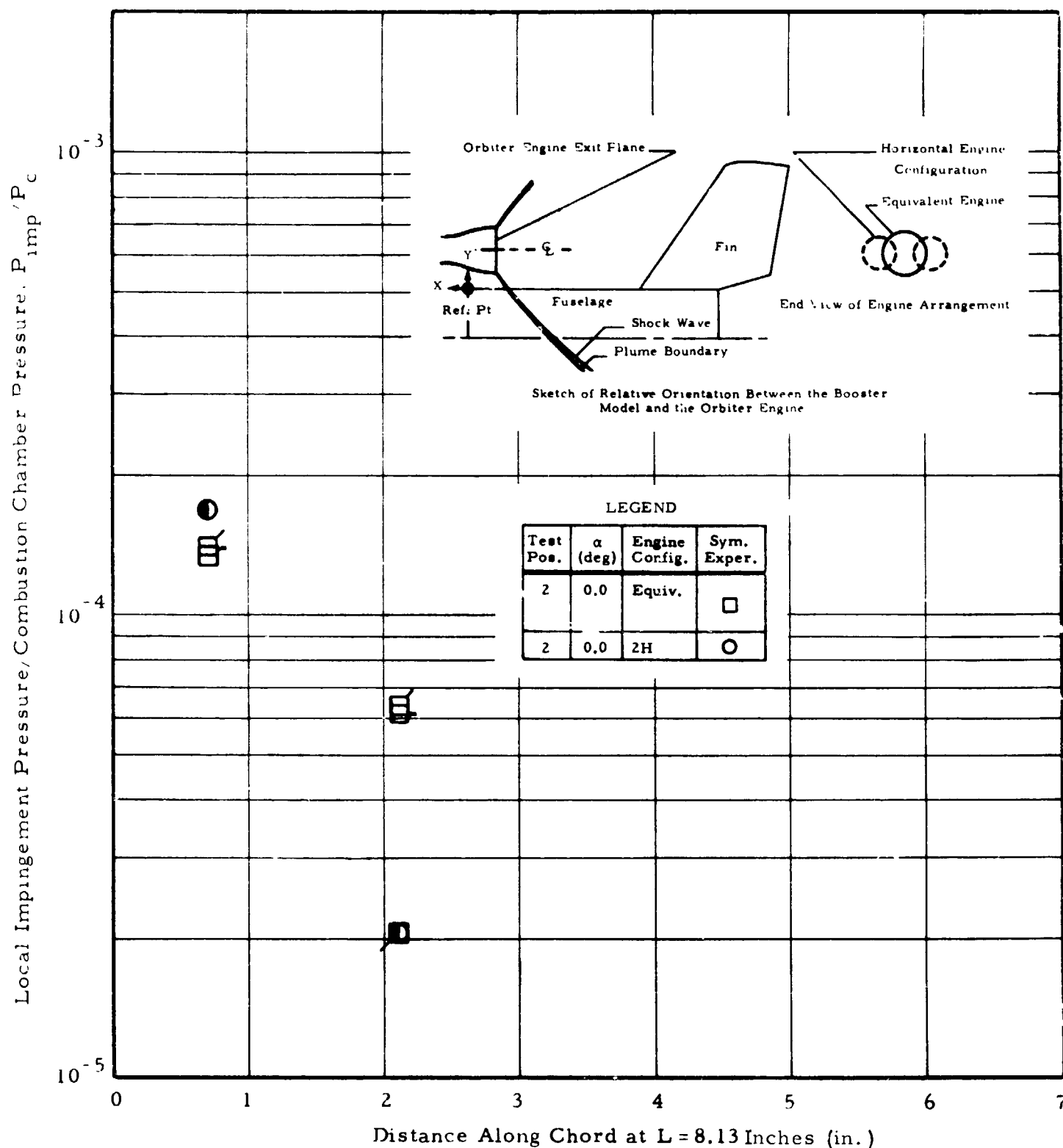


Fig. 53 - Impingement Pressure Distribution Along the Dorsal Fin Chord (Test Pos. 2)

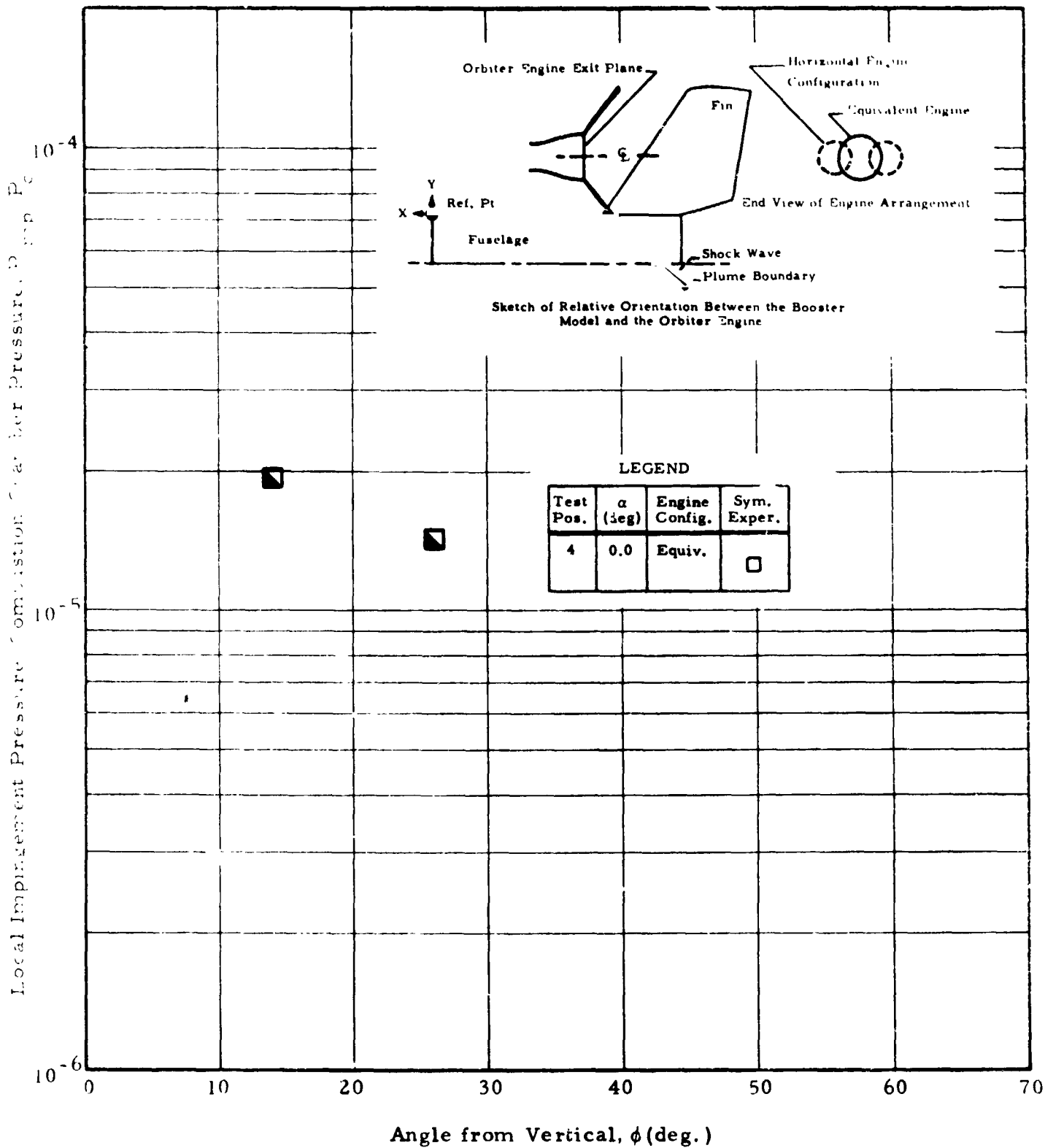


Fig. 54 - Impingement Pressure Distribution over the Booster Fuselage at Station 102.12 (Test Pos. 4)

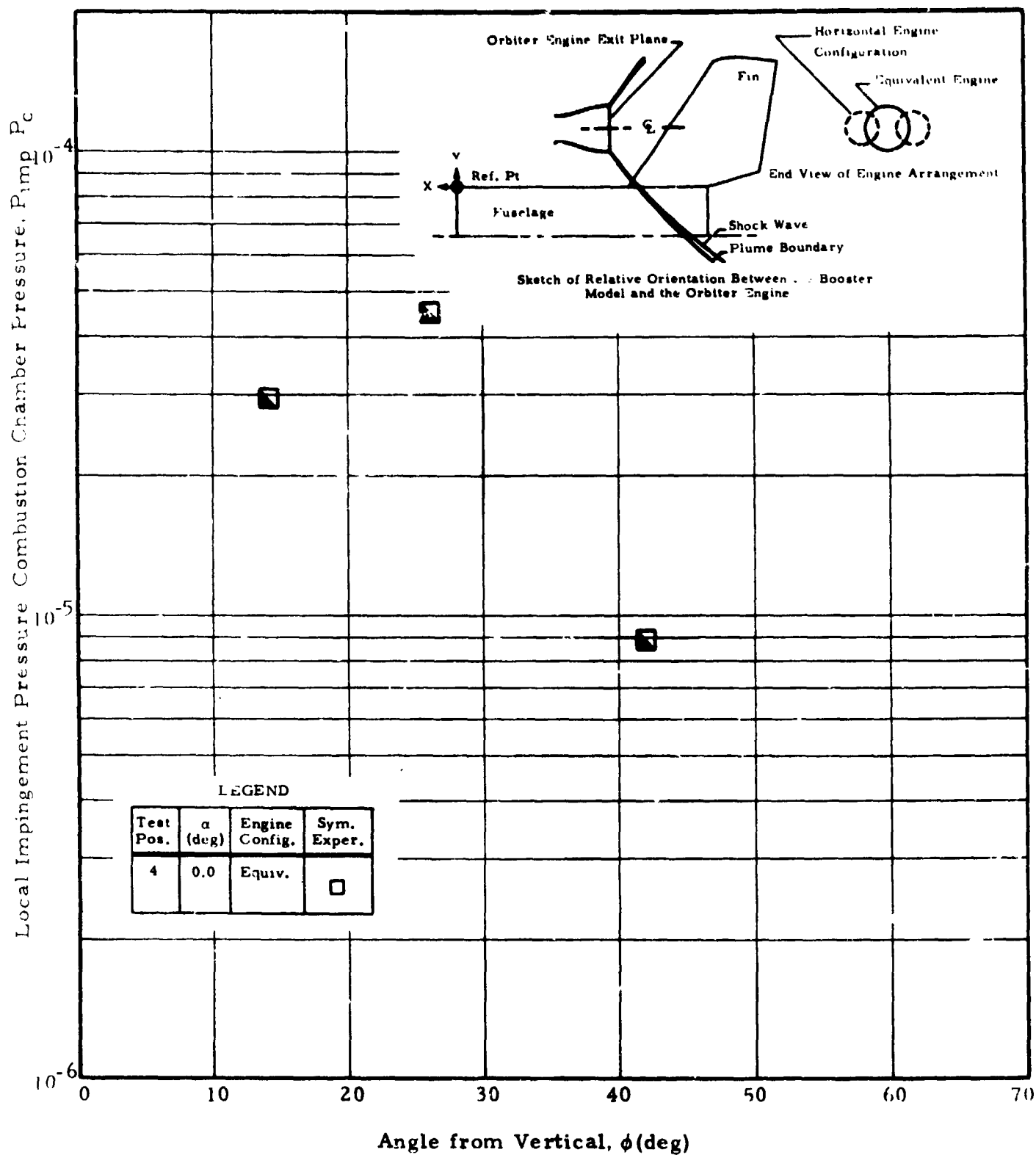


Fig. 55 - Impingement Pressure Distribution over the Booster Fuselage Surface at Station 105.12 (Test Pos. 4)

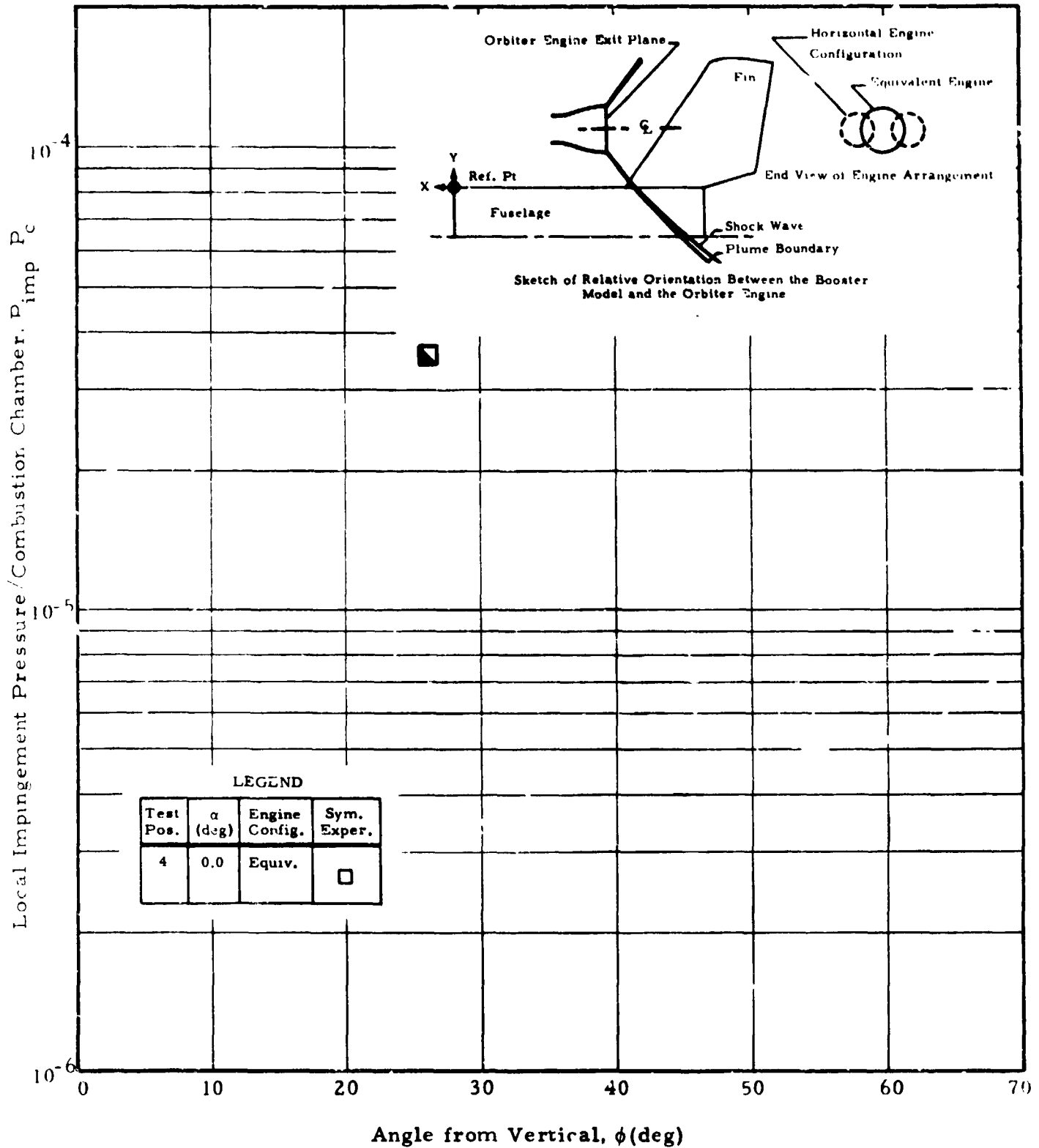


Fig. 56 - Impingement Pressure Distribution over the Booster Fuselage at Station 107.12 (Test Pos. 4)

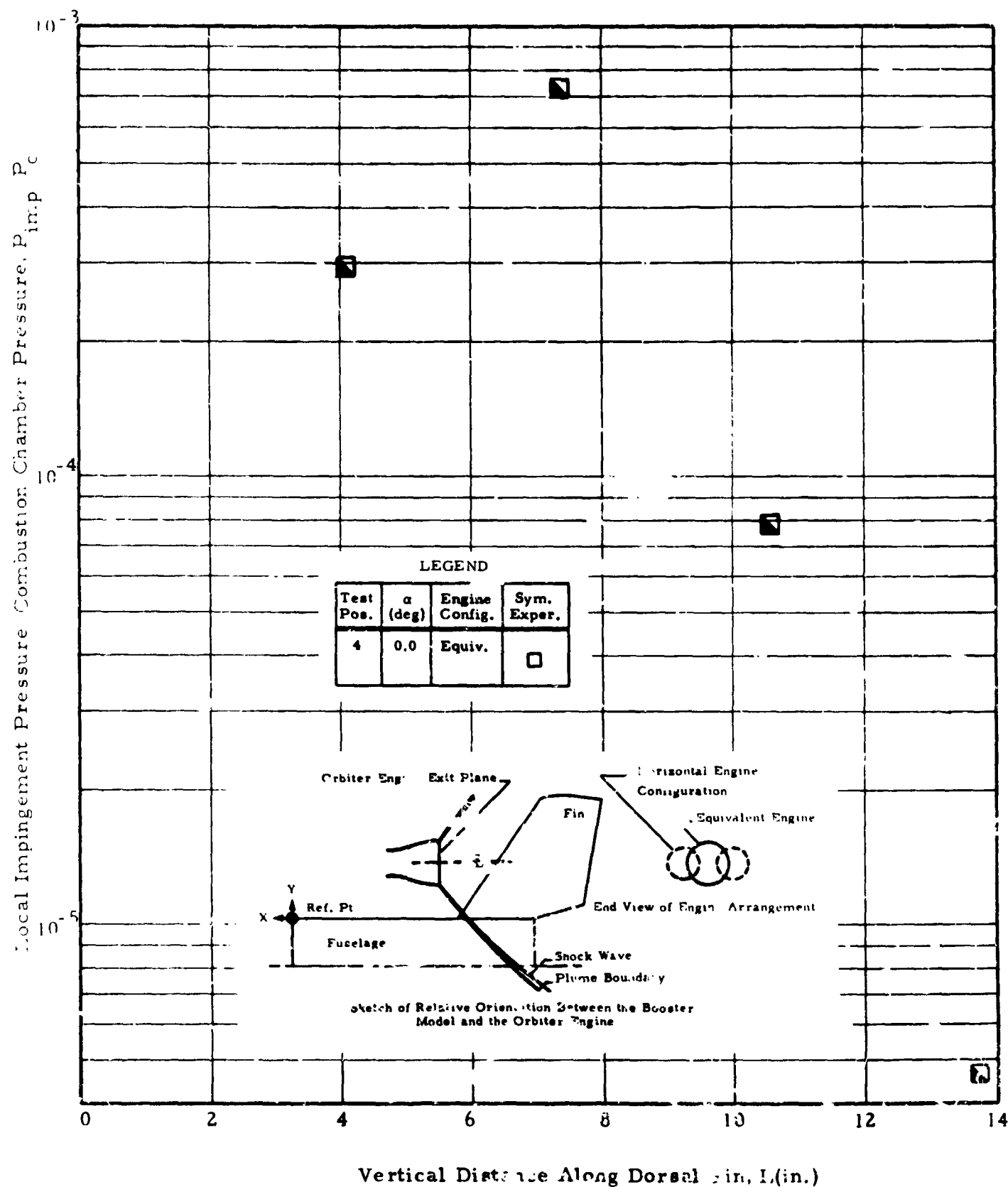


Fig. 57 - Impingement Pressure Distribution Along the Dorsal Fin Leading Edge (Test Pos. 4)

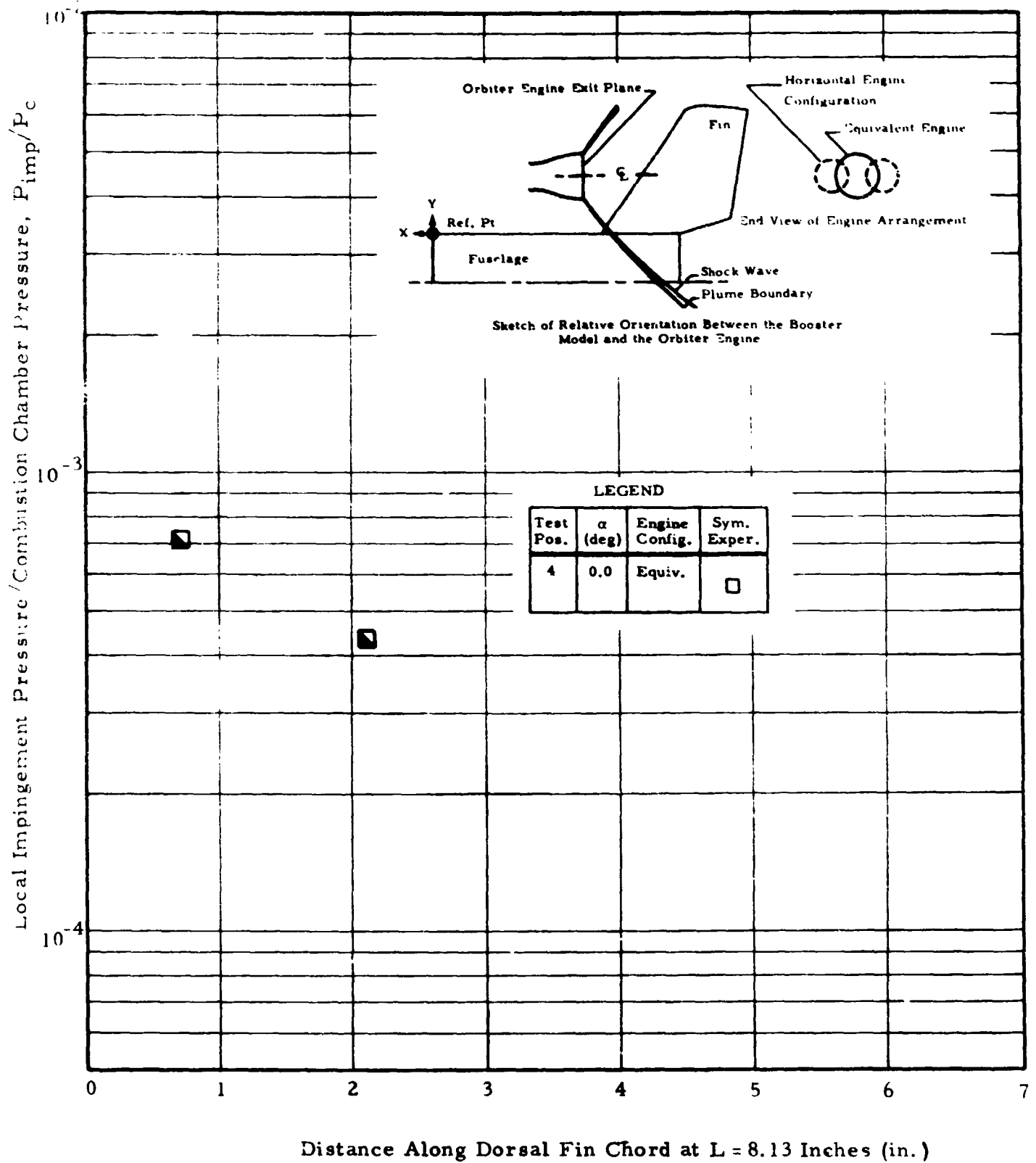


Fig. 58 - Impingement Pressure Distribution Along the Dorsal Fin Chord (Test Pos. 4)

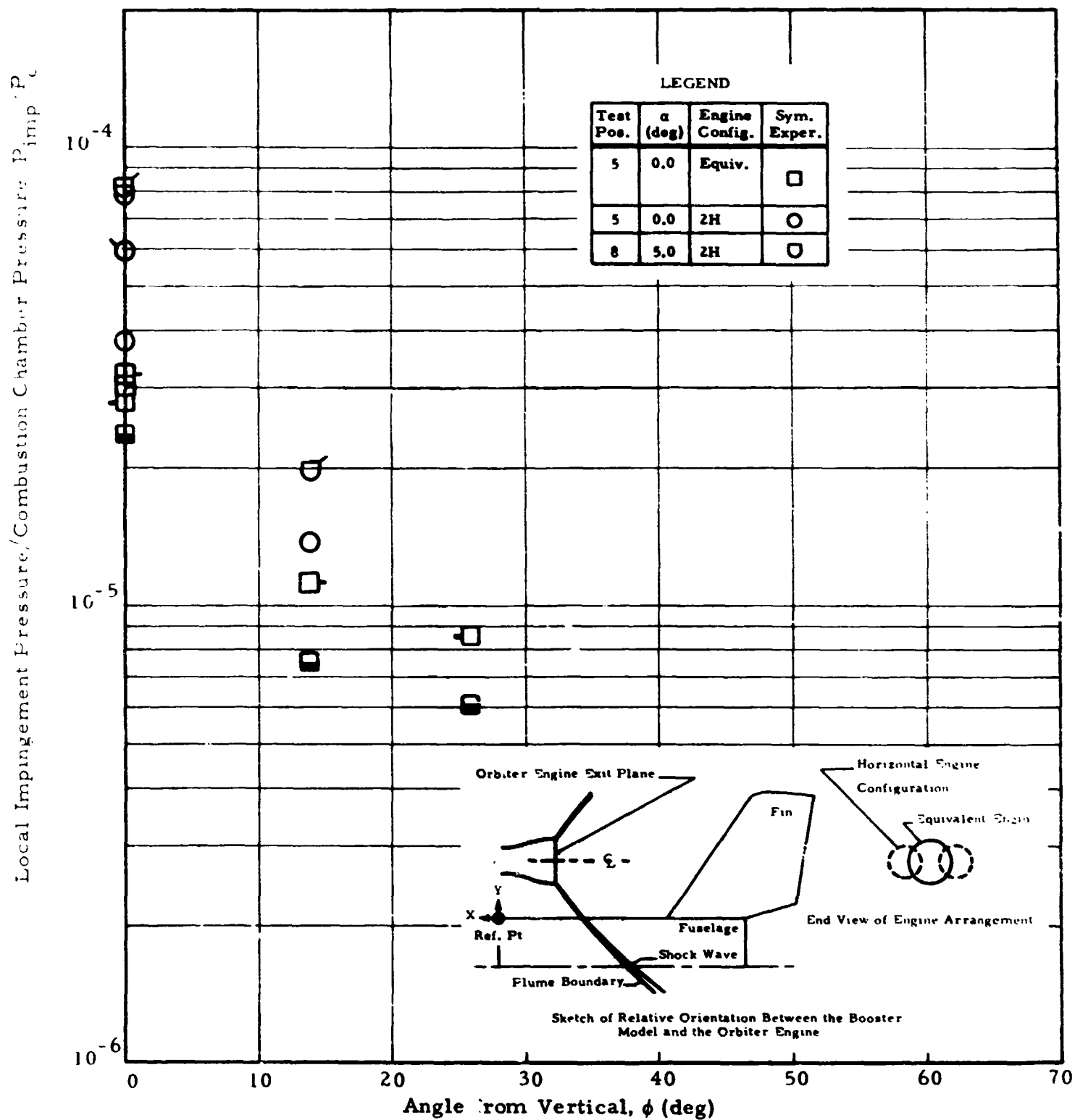


Fig. 59 - Impingement Pressure Distribution over the Booster Fuselage at Station 90.12 (Test Pos. 5 and Test Pos. 8)

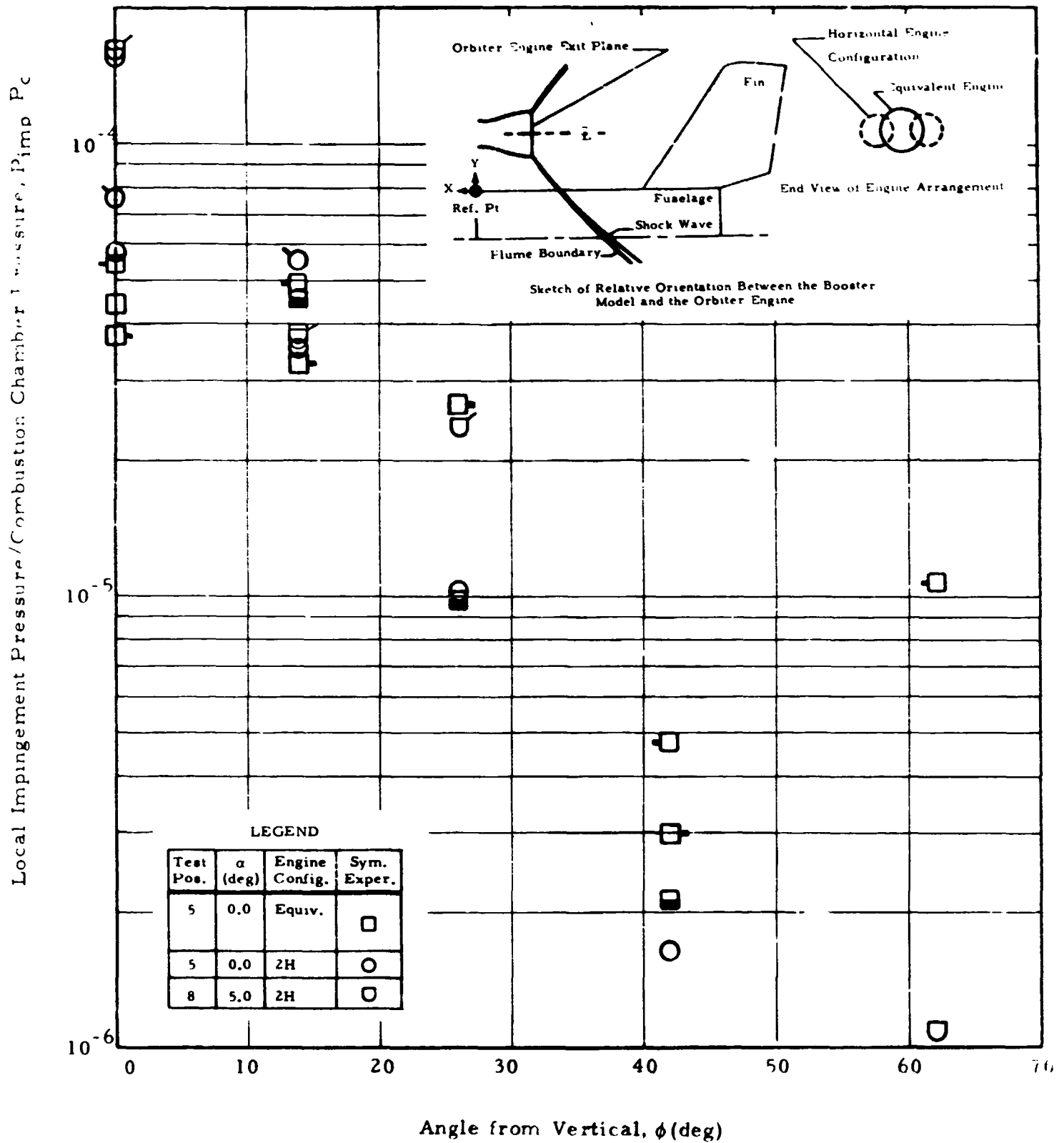


Fig. 60 - Impingement Pressure Distribution over the Booster Fuselage at Station 93.12 (Test Pos. 5 and Test Pos. 8)

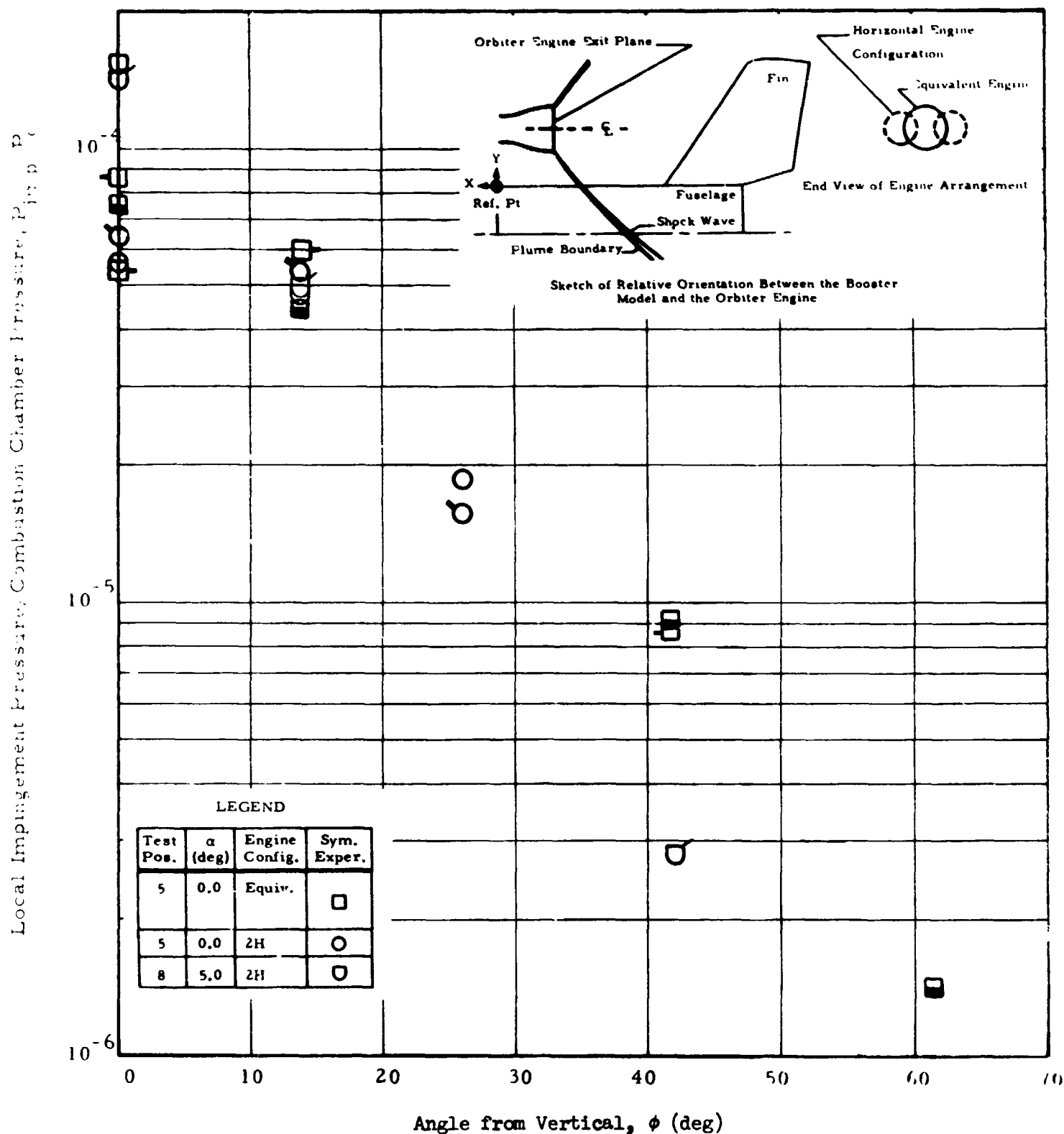


Fig. 61 - Impingement Pressure Distribution over the Booster Fuselage at Station 96.12 (Test Pos. 5 and Test Pos. 8)

Local Impingement Pressure/Combustion Chamber Pressure,  $P_{imp}/P_c$

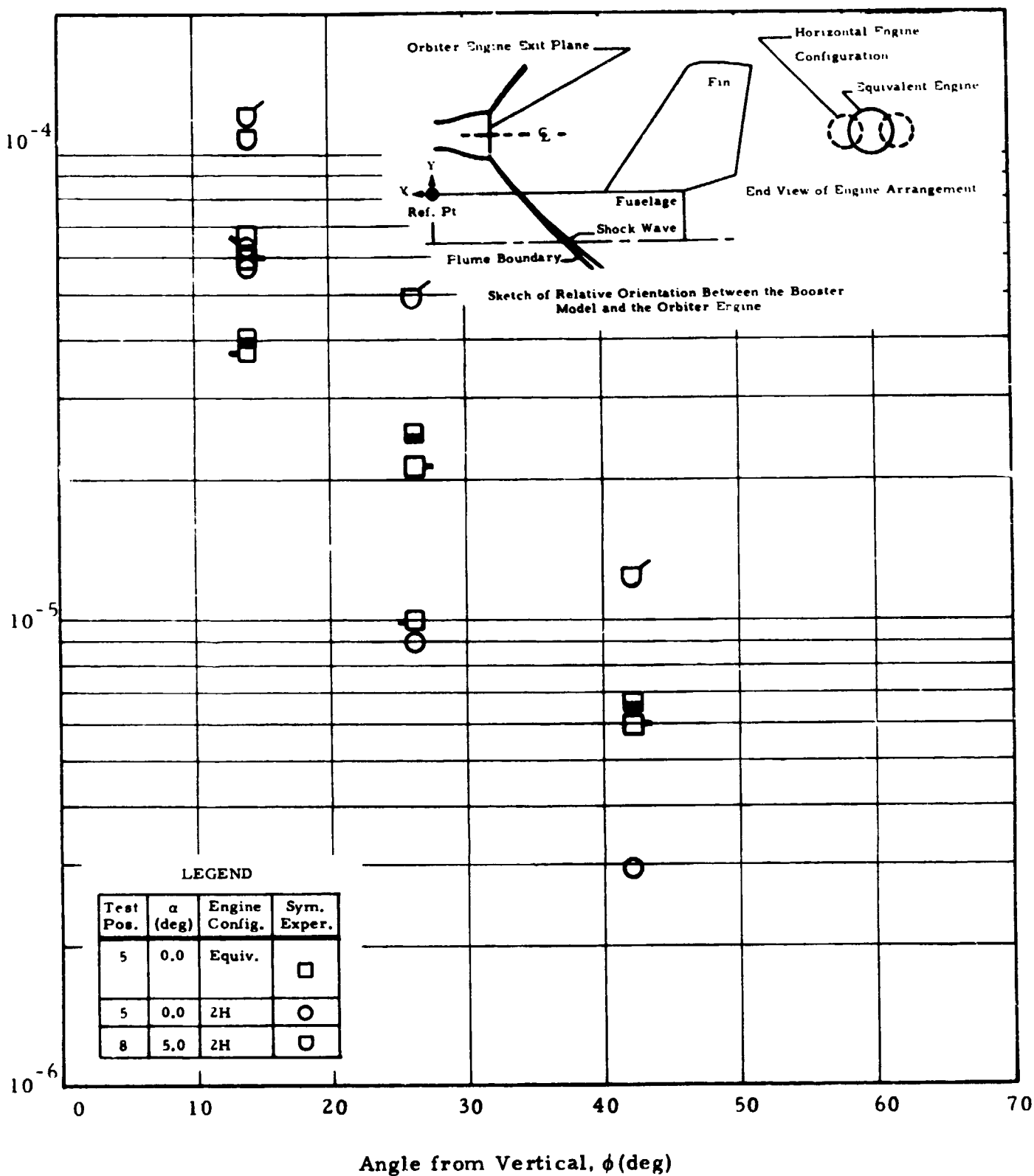


Fig. 62 - Impingement Pressure Distribution over the Booster Fuselage at Station 99.12 (Test Pos. 5 and Test Pos. 8)

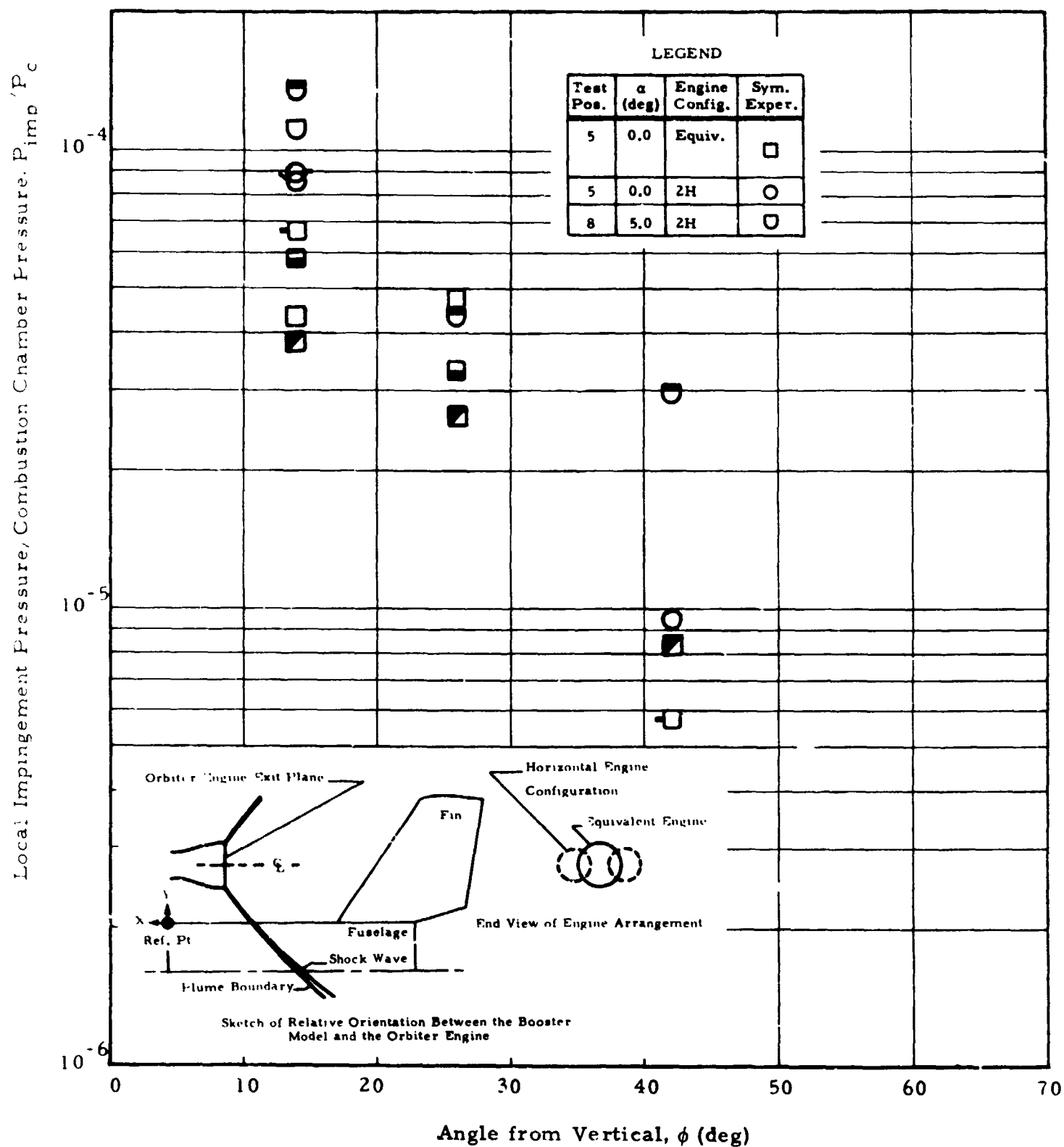


Fig. 63 - Impingement Pressure Distribution over the Booster Fuselage at Station 102.12 (Test Pos. 5 and Test Pos. 8)

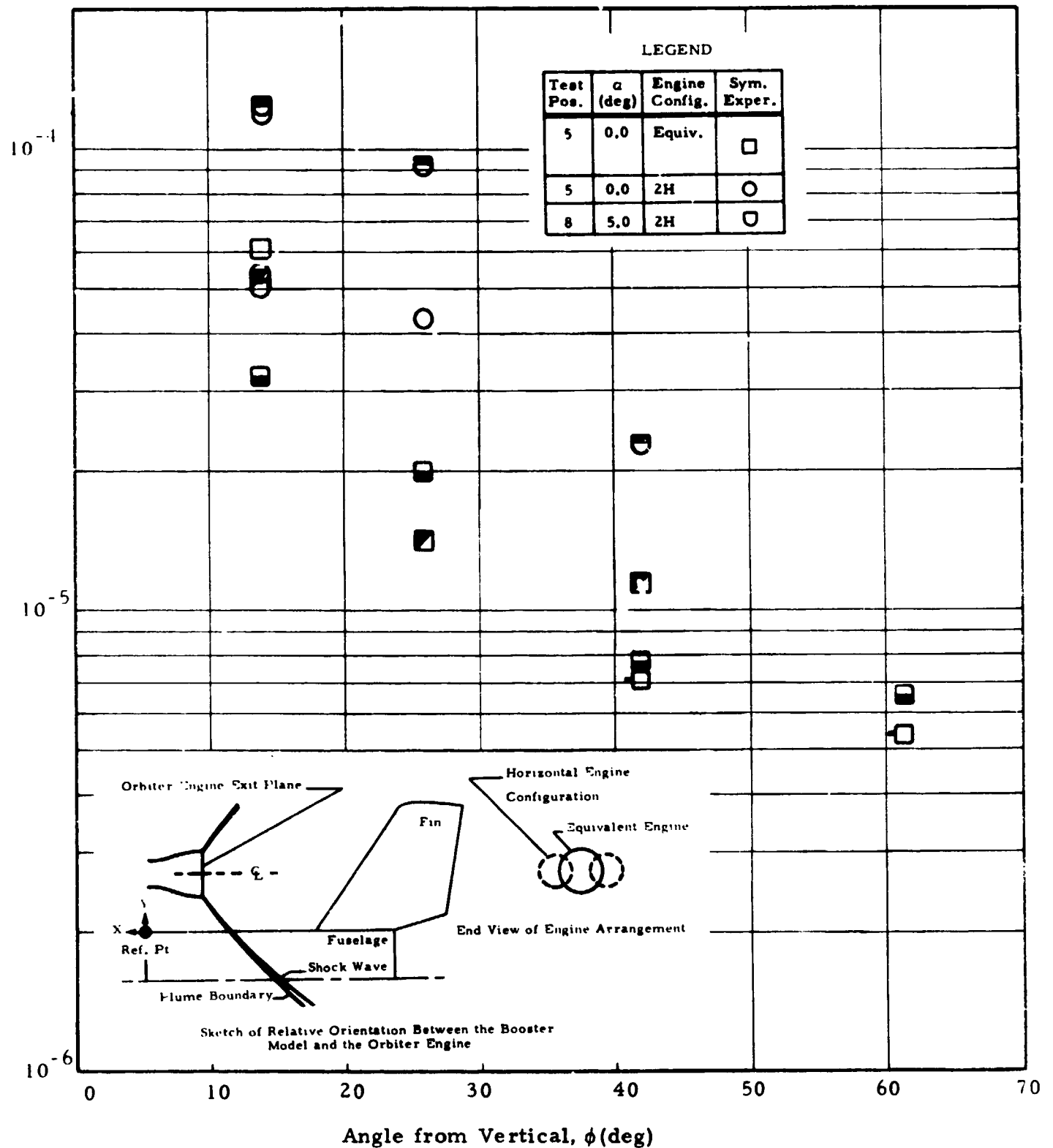
Local Impingement Pressure/Combustion Chamber Pressure,  $P_{imp}/P_c$ 


Fig. 64 - Impingement Pressure Distribution over the Booster Fuselage at Station 105.12 (Test Pos. 5 and Test Pos. 8)

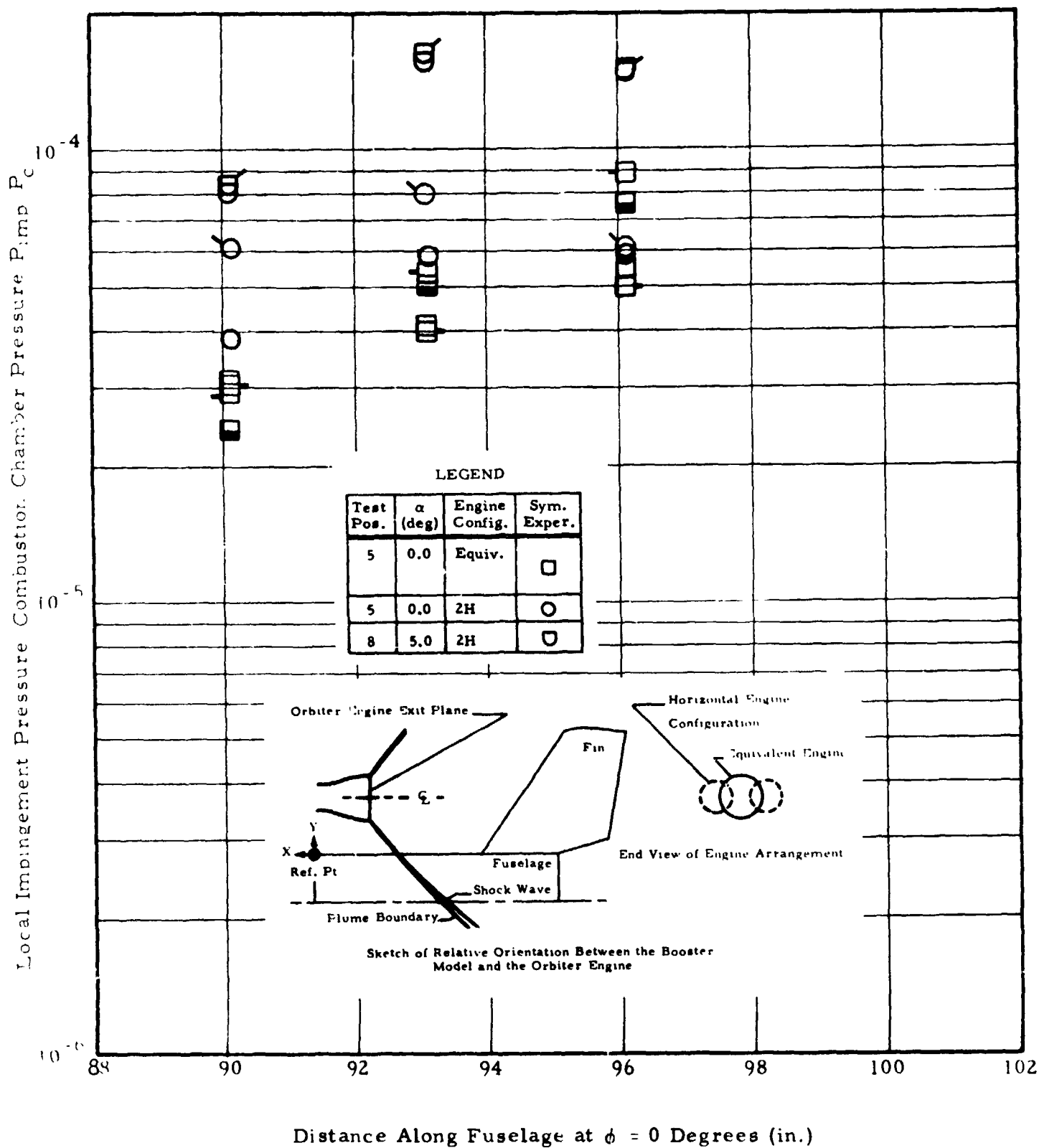


Fig. 65 - Impingement Pressure Distribution Along Fuselage Stagnation Line (Test Pos. 5 and Test Pos. 8)

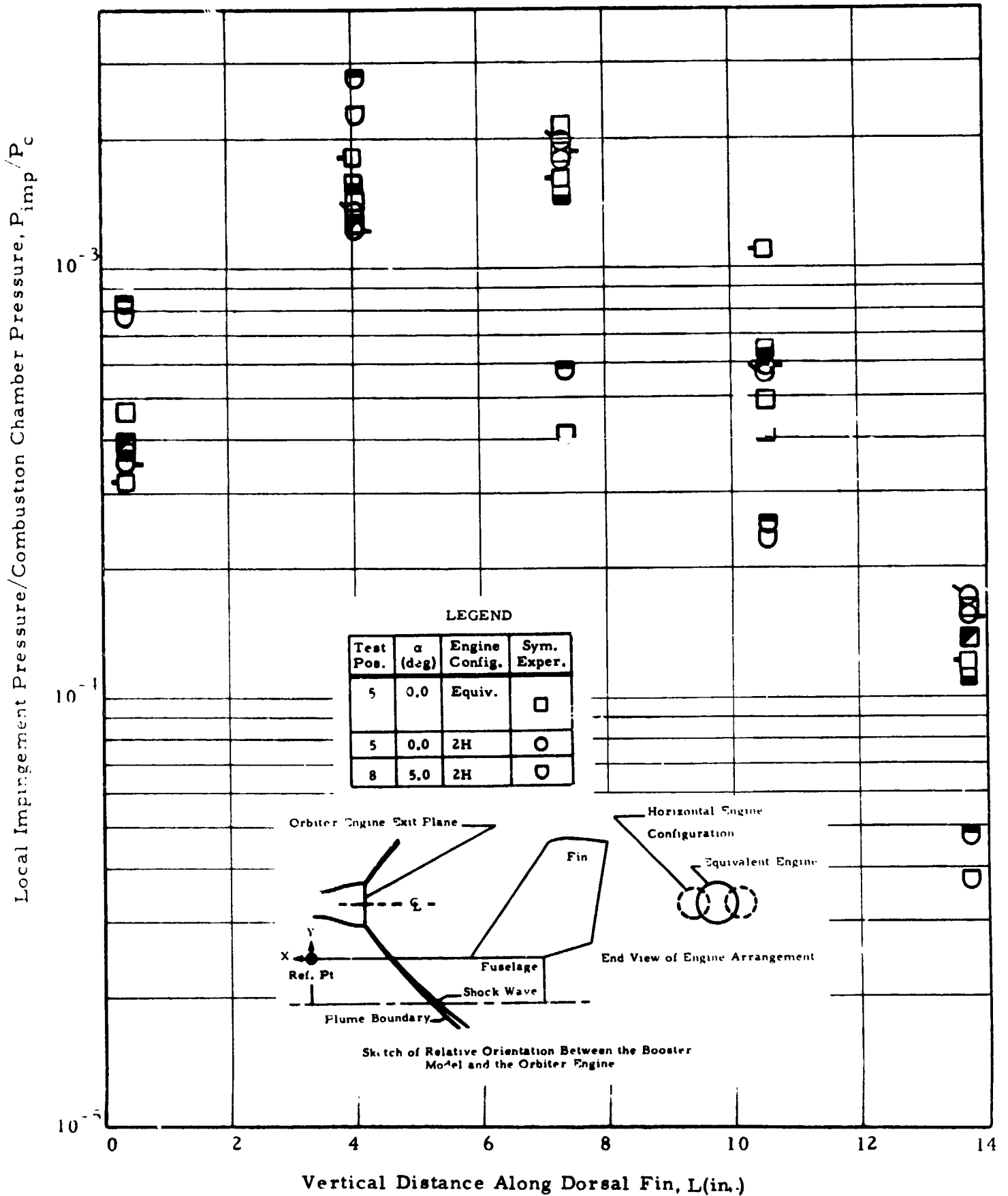


Fig. 66 - Impingement Pressure Distribution Along Dorsal Fin Leading Edge  
(Test Positions 5 and 8)

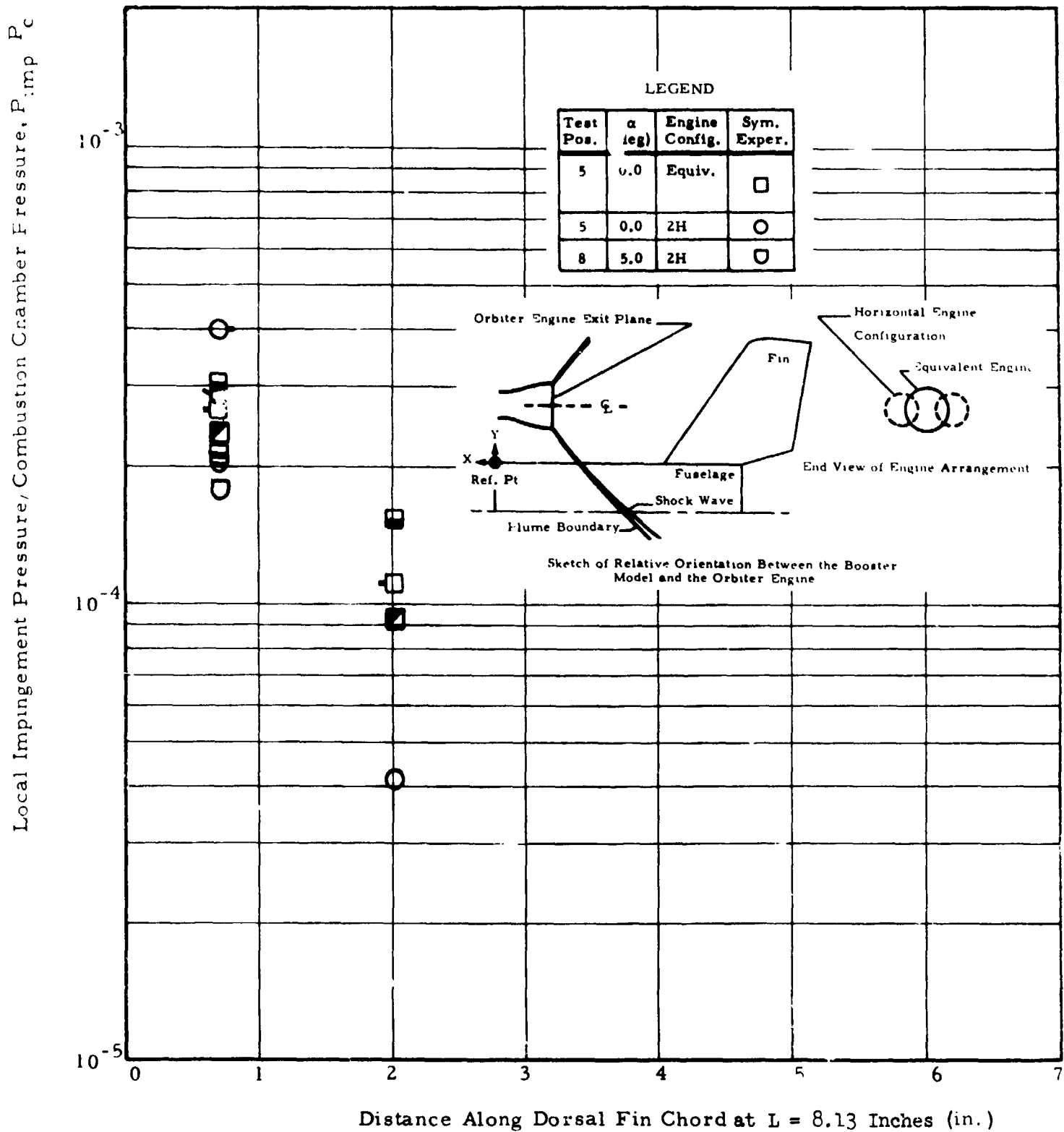


Fig. 67 - Impingement Pressure Distribution Along Dorsal Fin Chord (Test Pos. 5 and Test Pos. 8)

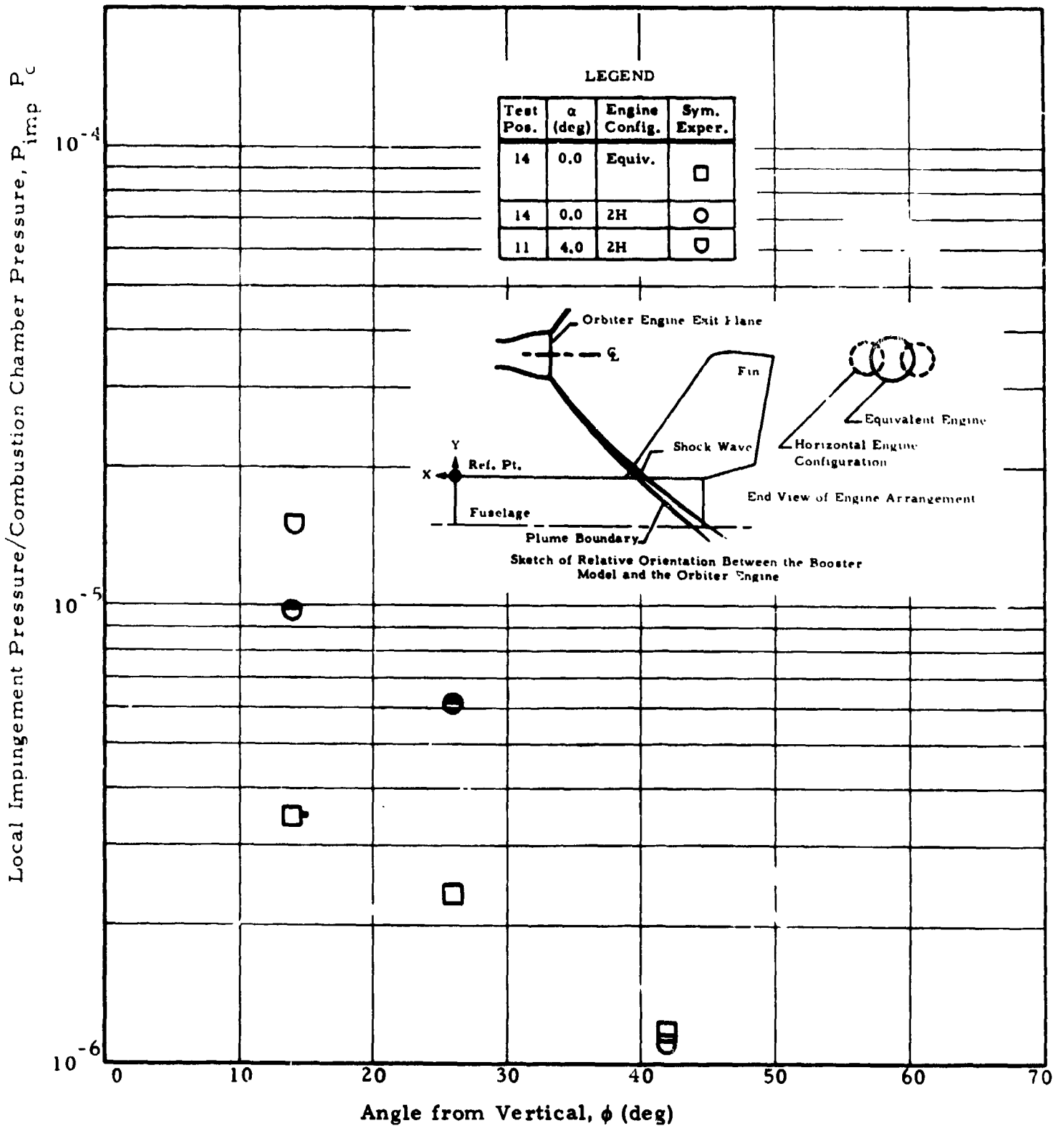


Fig. 68 - Impingement Pressure Distribution over the Booster Fuselage at Station 102.12 (Test Pos. 11 and Test Pos. 14)

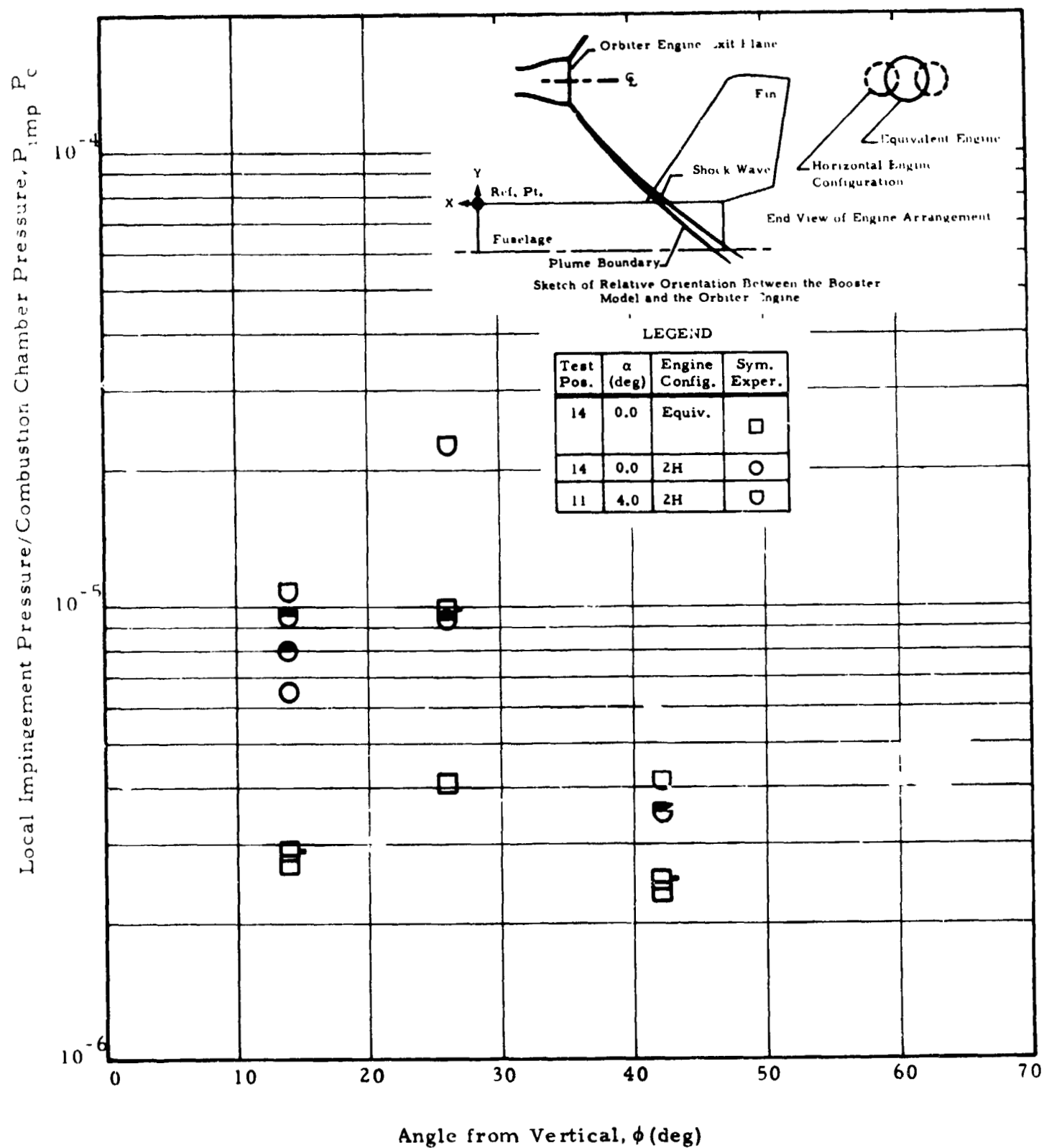


Fig. 69 - Impingement Pressure Distribution over the Booster Fuselage at Station 105.12 (Test Pos. 11 and Test Pos. 14)

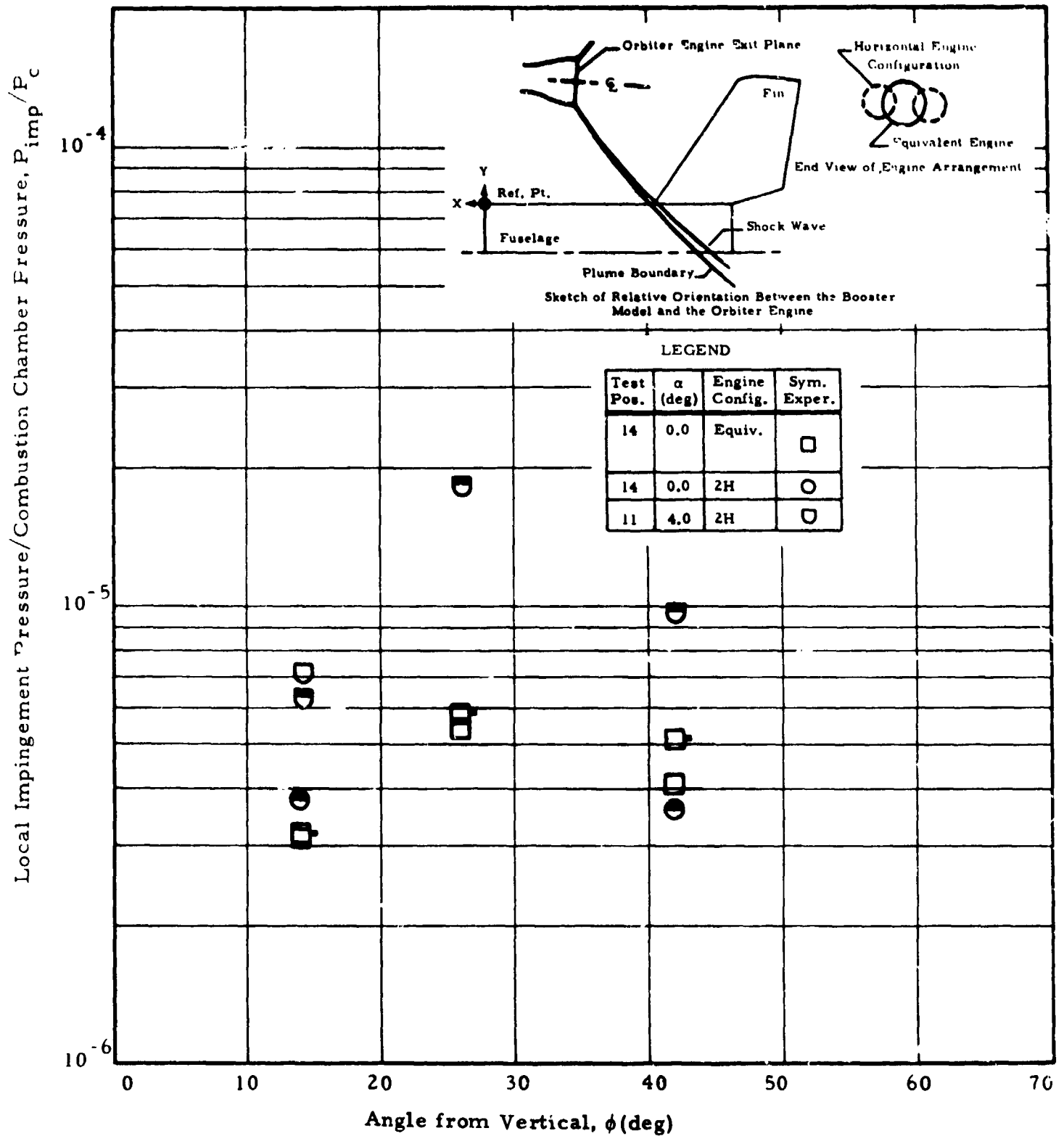


Fig. 70 - Impingement Pressure Distribution over the Booster Fuselage at Station 107.12 (Test Pos. 11 and Test Pos. 14)

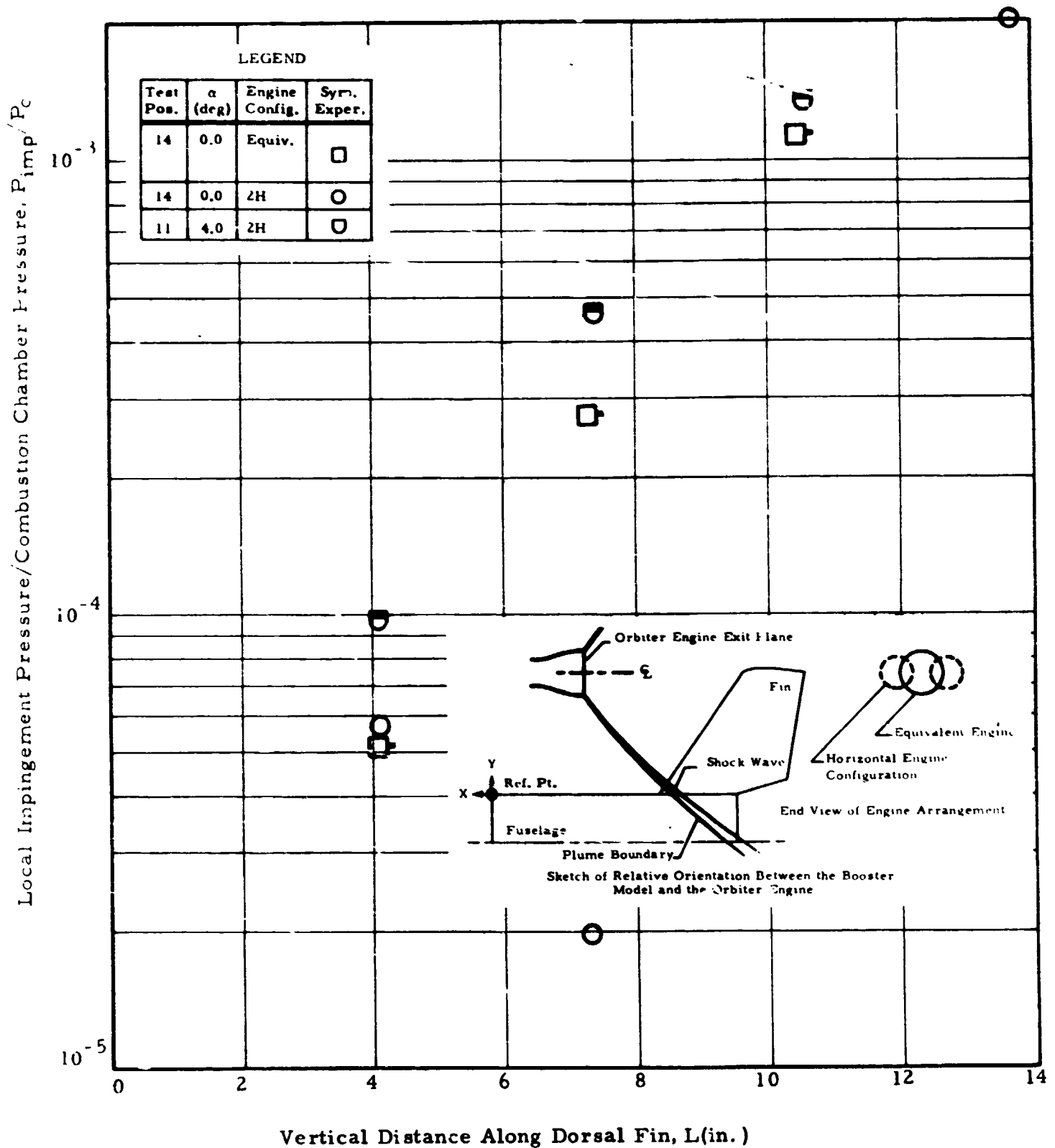


Fig. 71 - Impingement Pressure Distribution Along the Dorsal Fin Leading Edge (Test Pos 11 and Test Pos. 14)

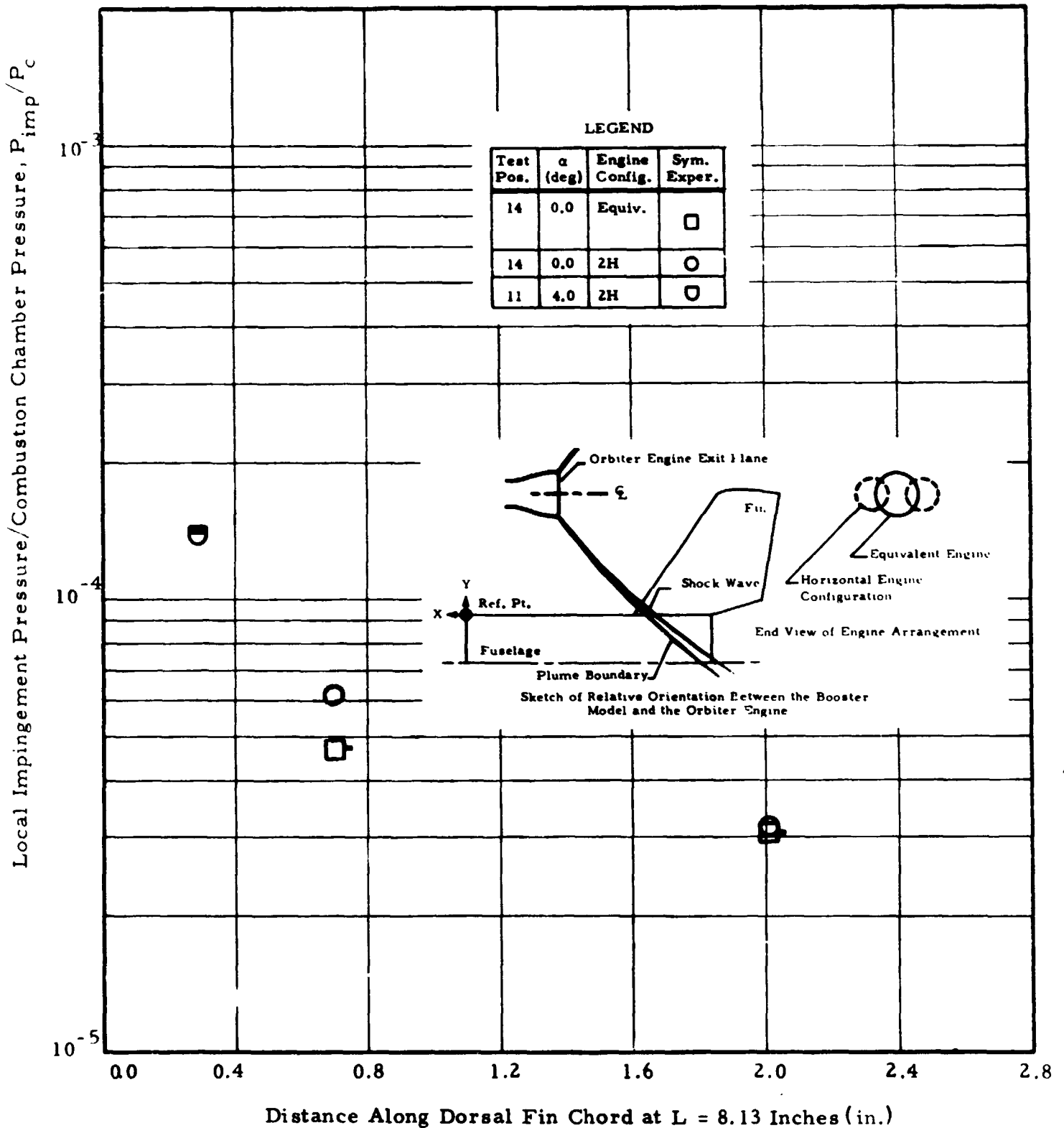


Fig. 72 - Impingement Pressure Distribution Along the Dorsal Fin Chord  
(Test Pos. 11 and Test Pos. 14)

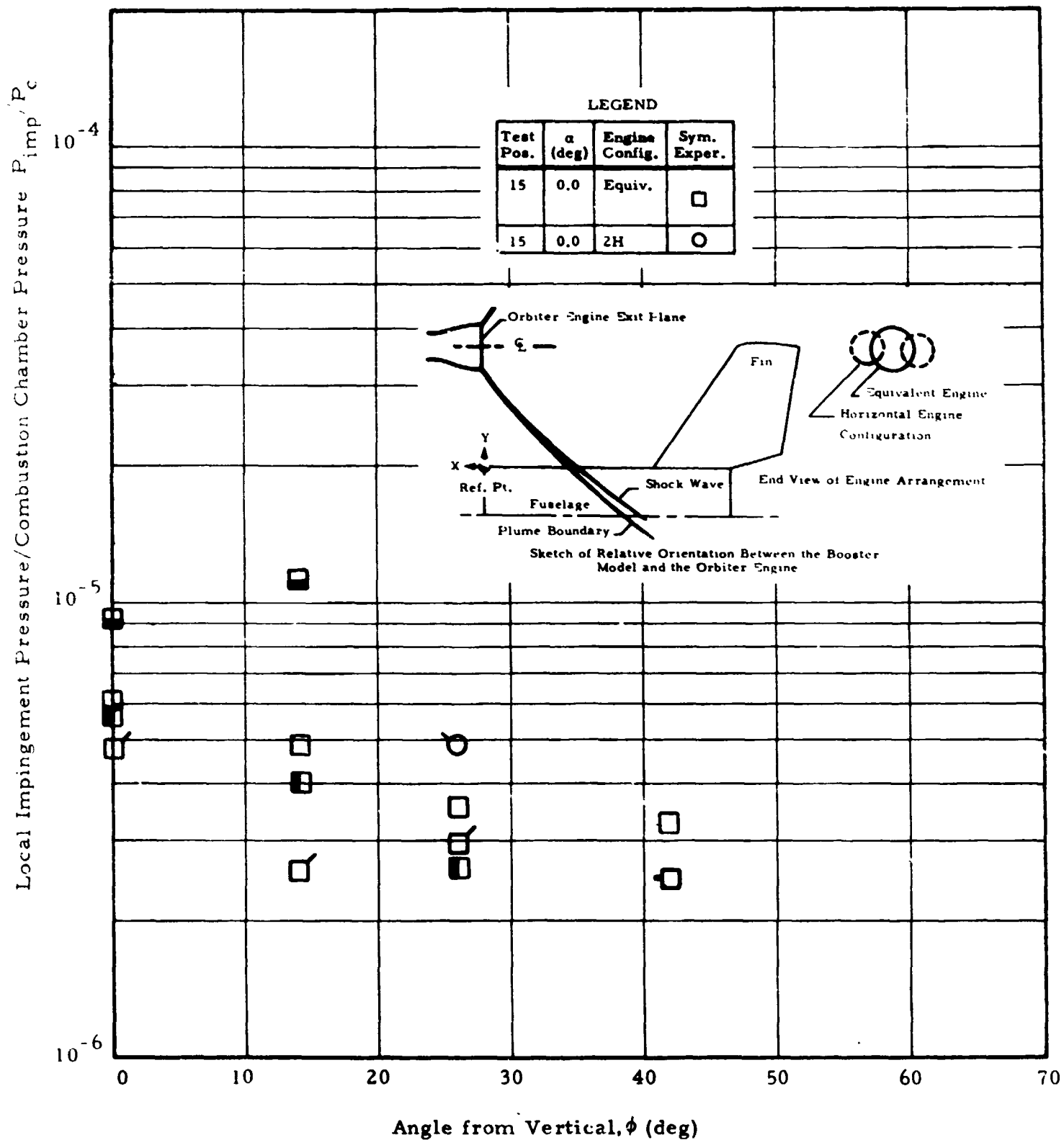


Fig. 73 - Impingement Pressure Distribution over the Booster Fuselage at Station 93.12 (Test Pos. 15)

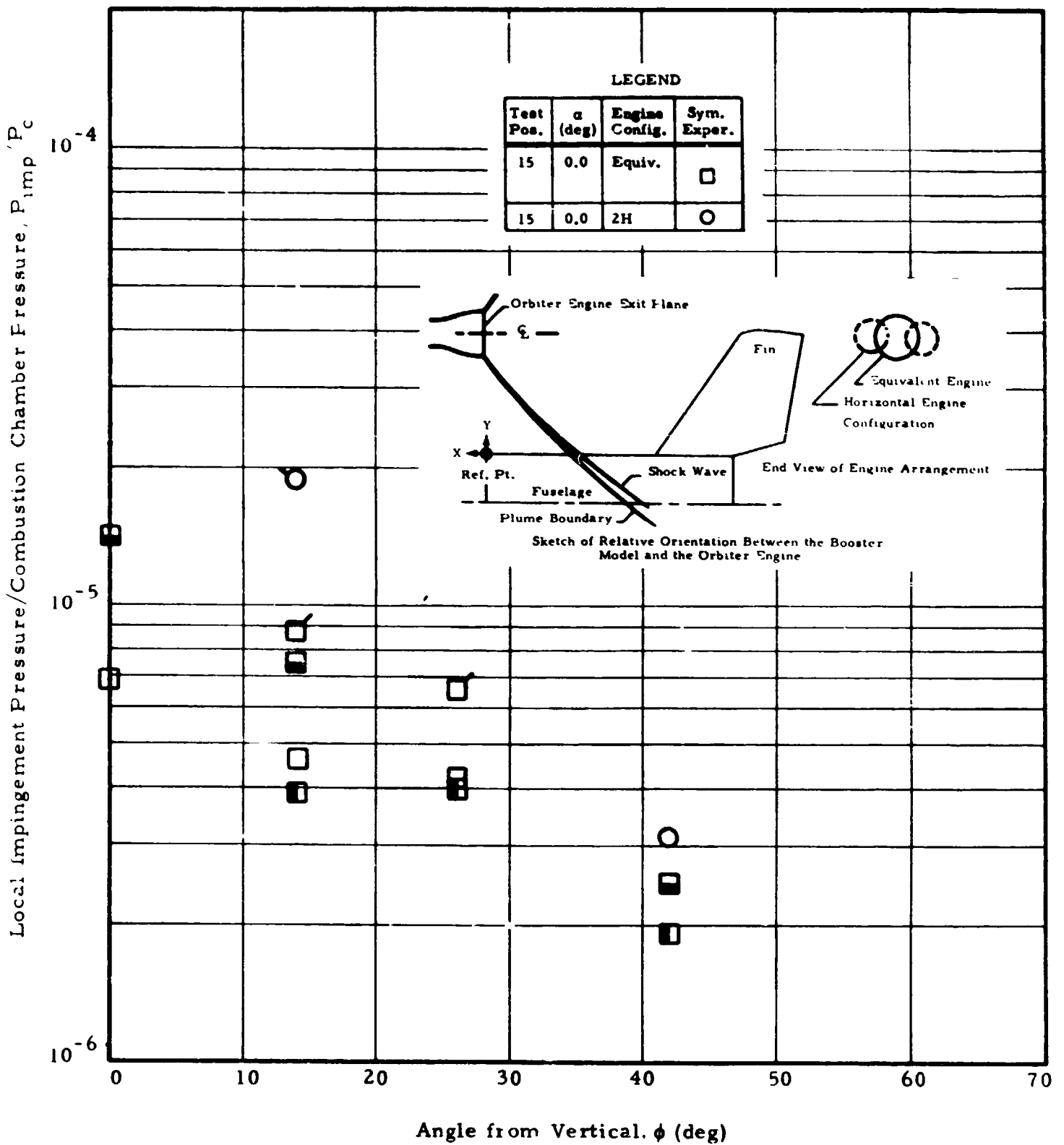


Fig. 74 - Impingement Pressure Distribution over the Booster Fuselage at Station 96.12 (Test Pos. 15)

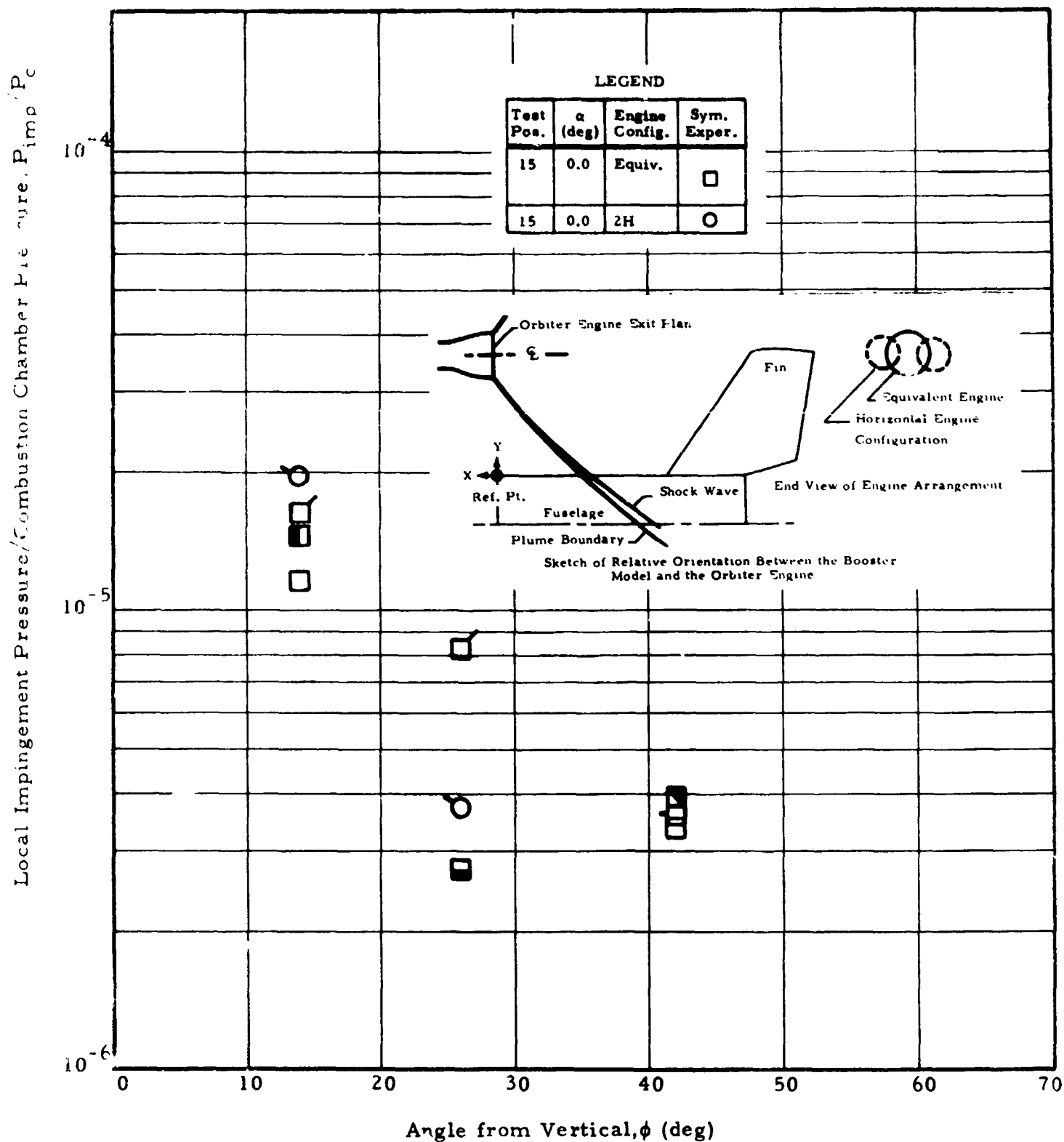


Fig. 75 - Impingement Pressure Distribution over the Booster Fuselage at Station 99.12 (Test Pos. 15)

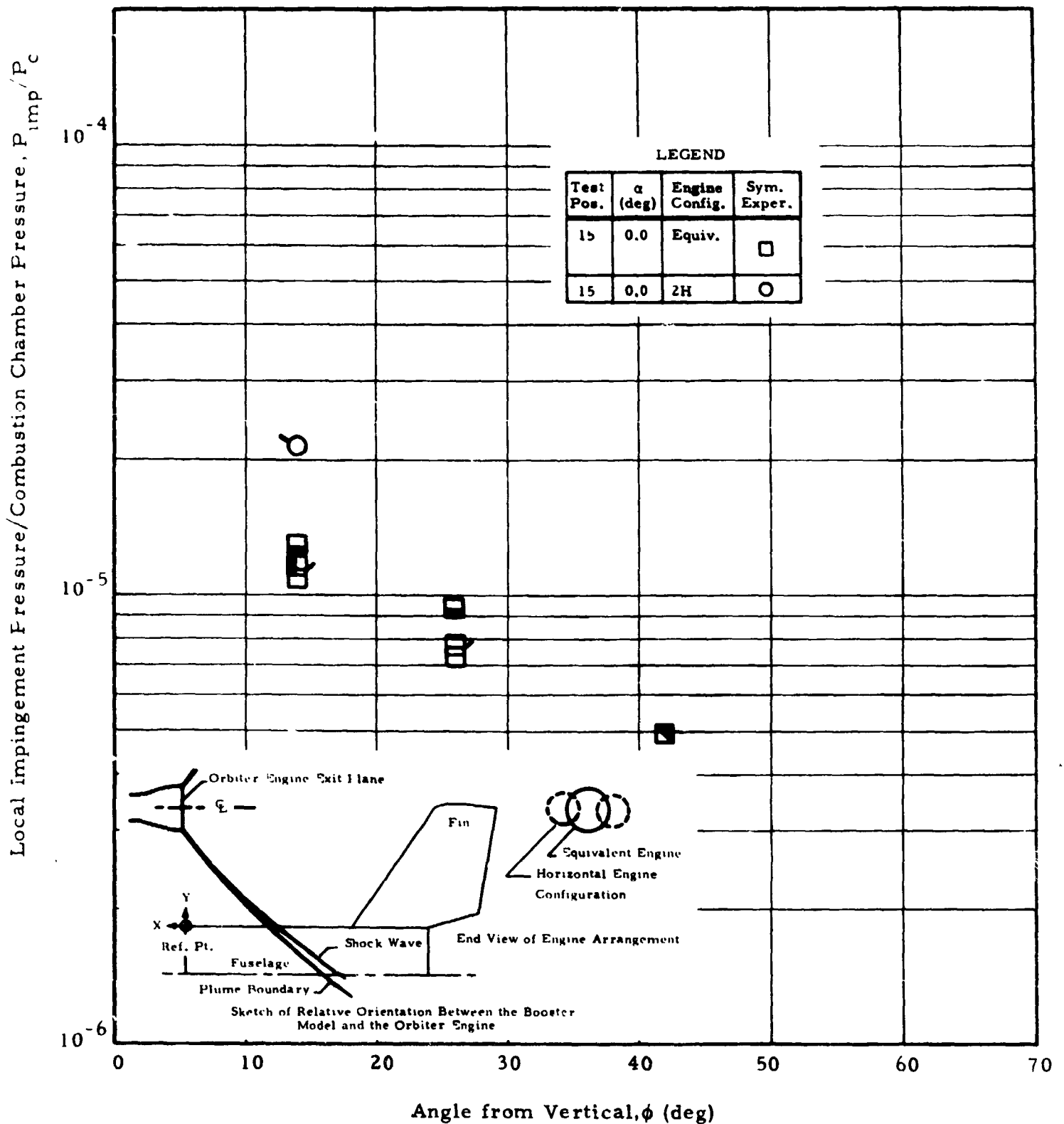


Fig. 76 - Impingement Pressure Distribution over the Booster Fuselage at Station 102.12 (Test Pos. 15)

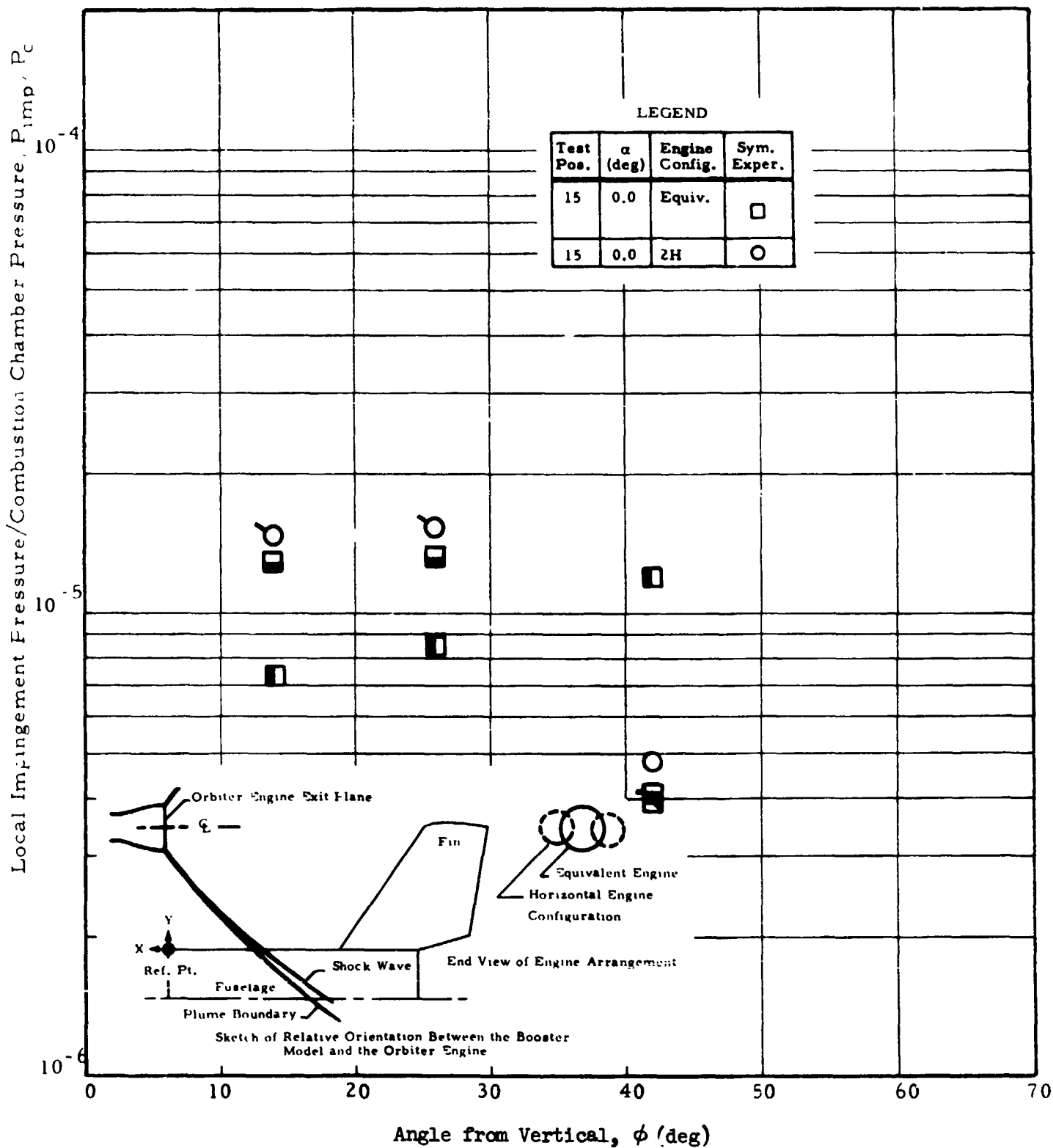


Fig. 77 - Impingement Pressure Distribution over the Booster Fuselage at Station 105.12 (Test Pos. 15)

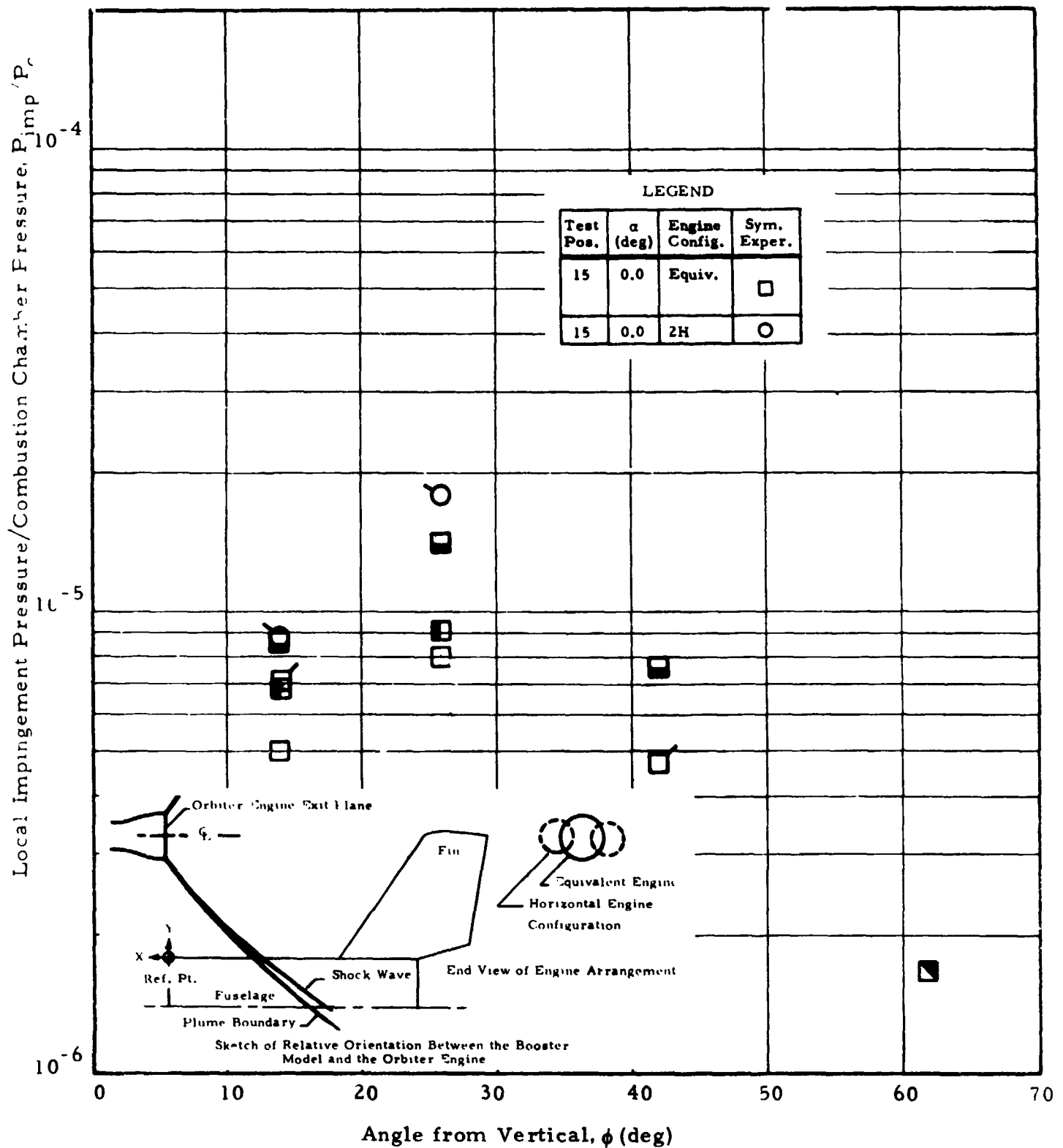


Fig. 78 - Impingement Pressure Distribution over the Booster Fuselage at Station 107.12 (Test Pos. 15)

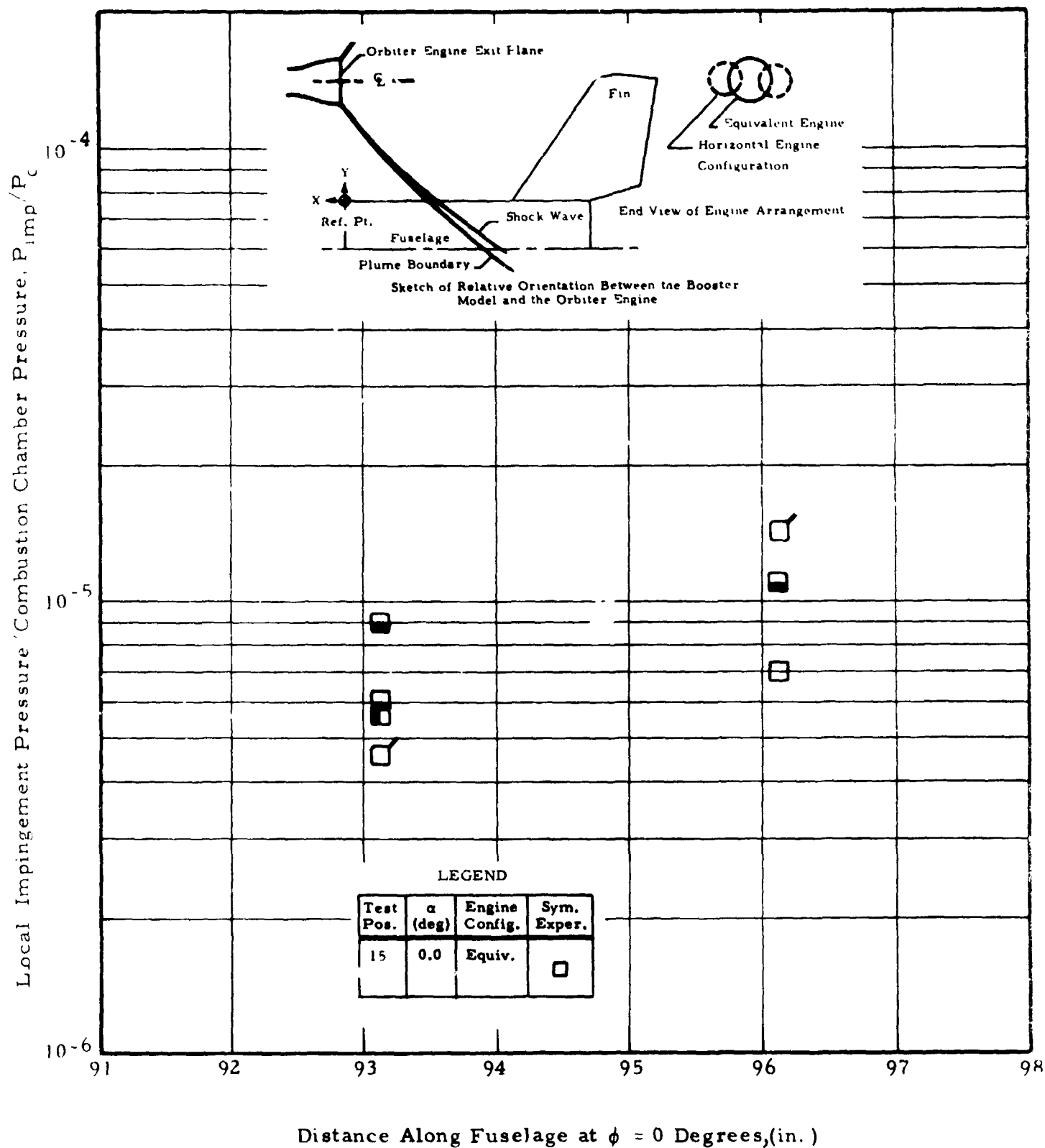


Fig. 79 - Impingement Pressure Distribution Along Fuselage Stagnation Line (Test Pos. 15)

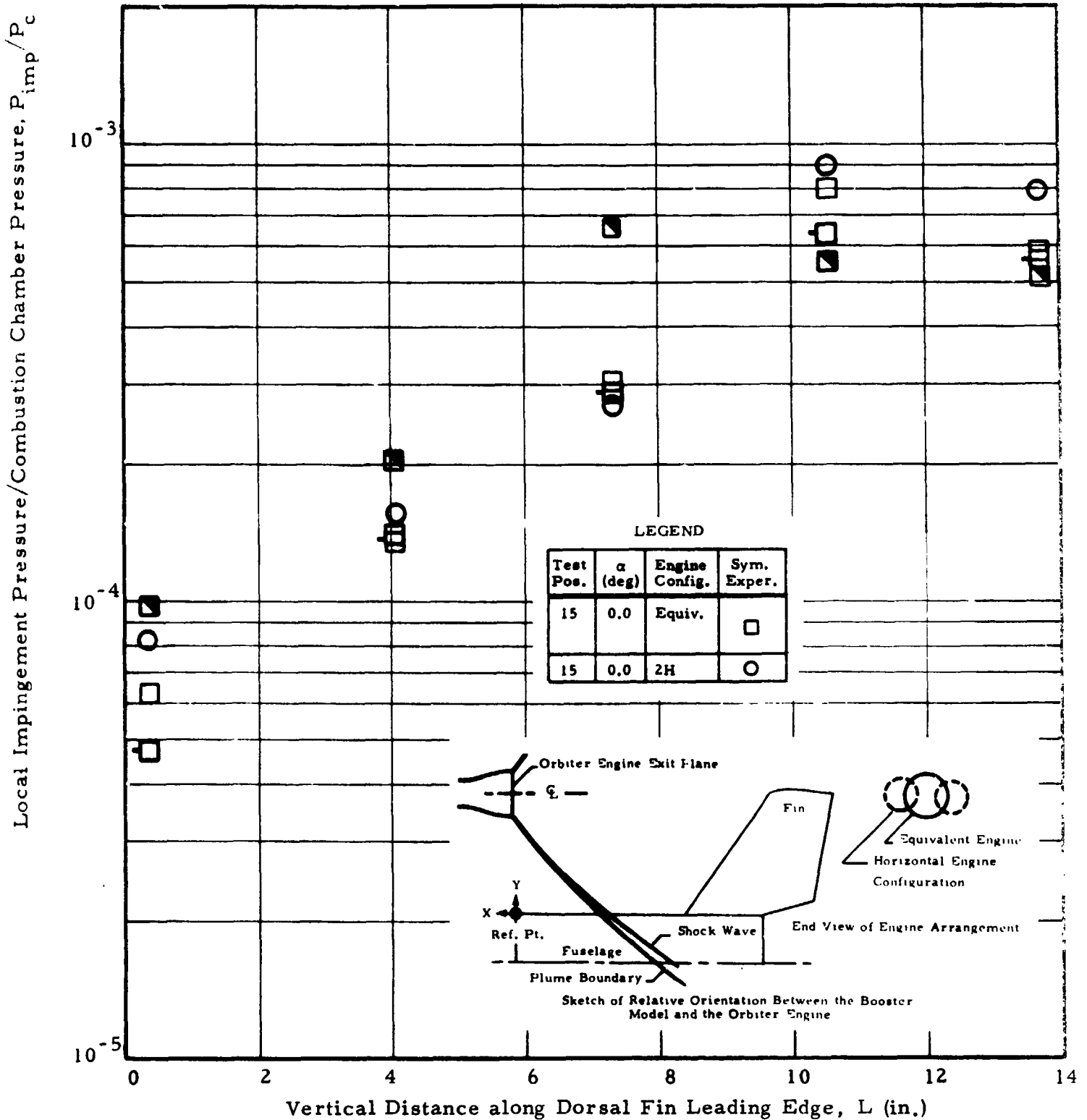


Fig. 80 - Impingement Pressure Distribution along the Dorsal Fin Leading Edge (Test Pos. 15)

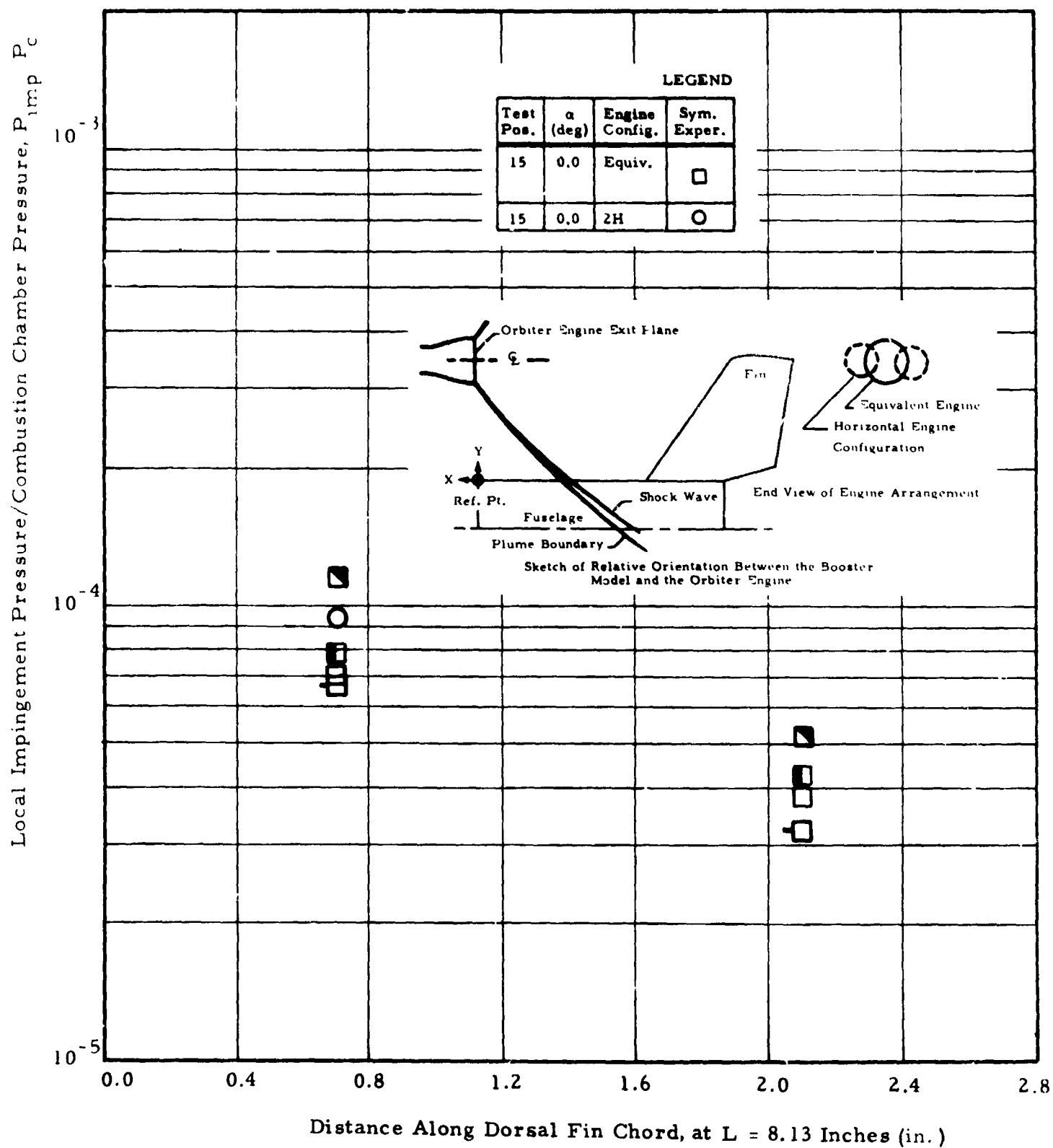


Fig. 81 - Impingement Pressure Distribution along the Dorsal Fin Chord (Test Pos. 15)

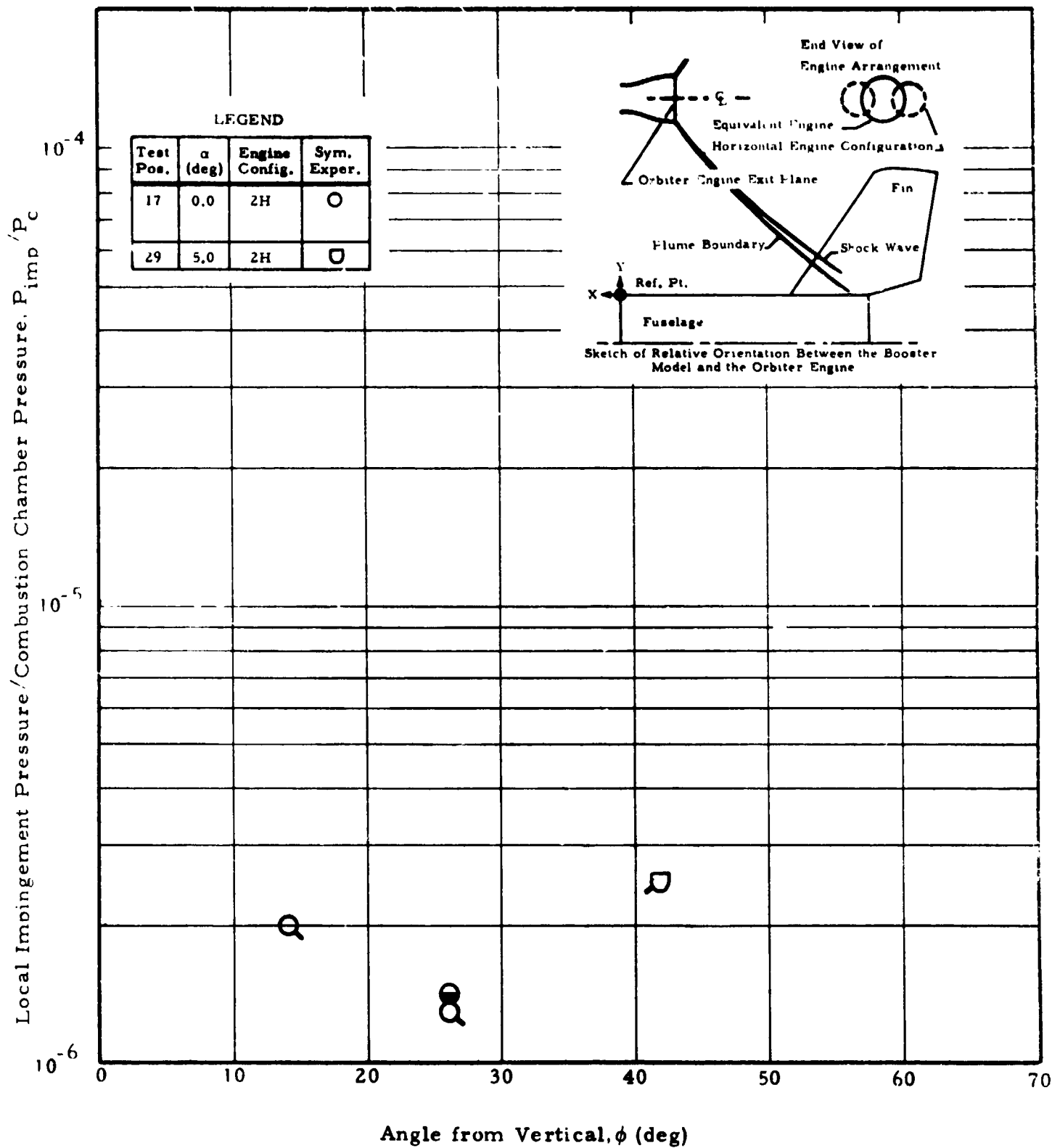


Fig. 82 - Impingement Pressure Distribution over the Booster Fuselage at Station 107.12 (Test Positions 17 and 29)

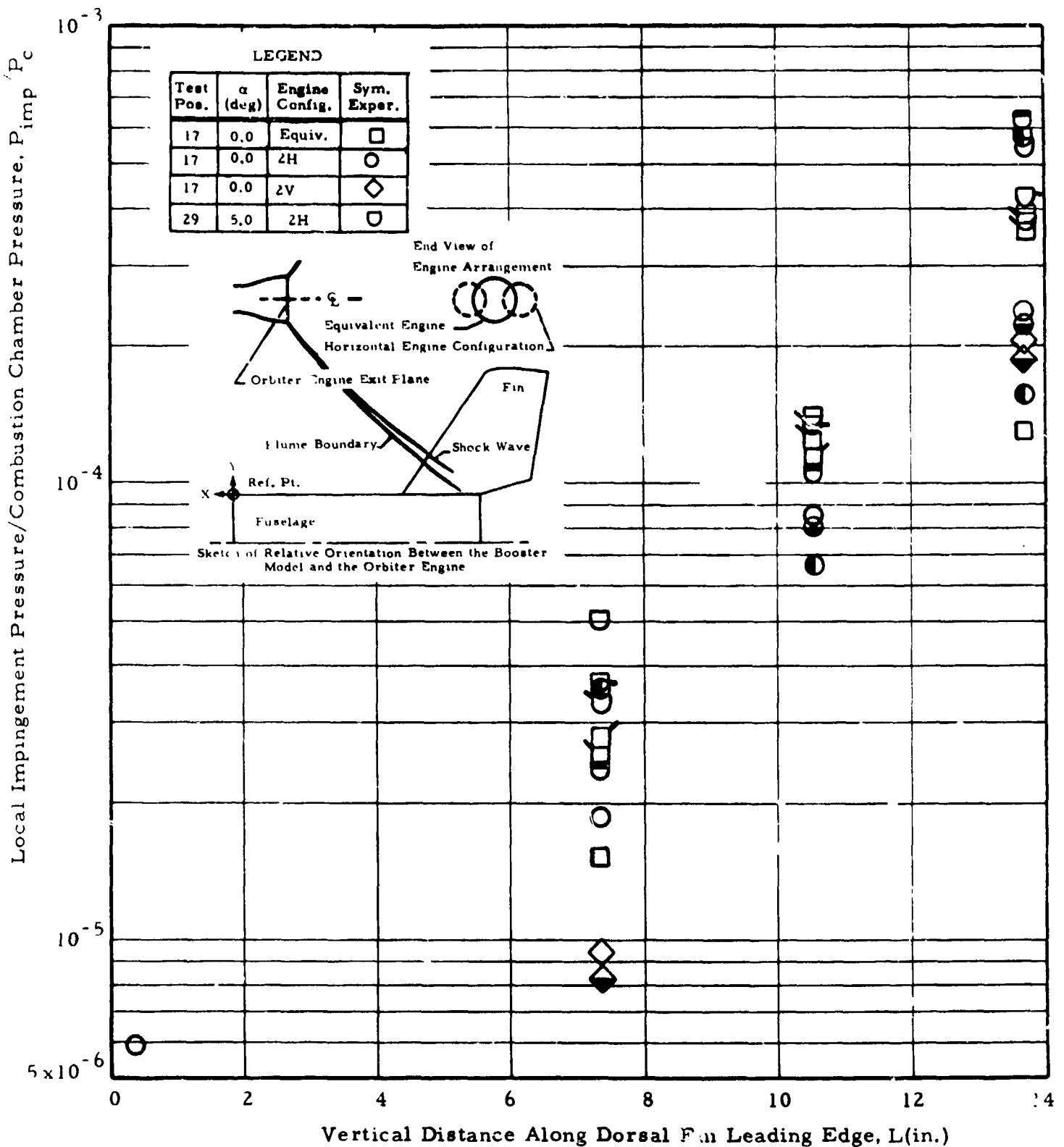


Fig. 83 - Impingement Pressure Distribution Along the Dorsal Fin Leading Edge (Test Pos. 17 and Test Pos. 29)

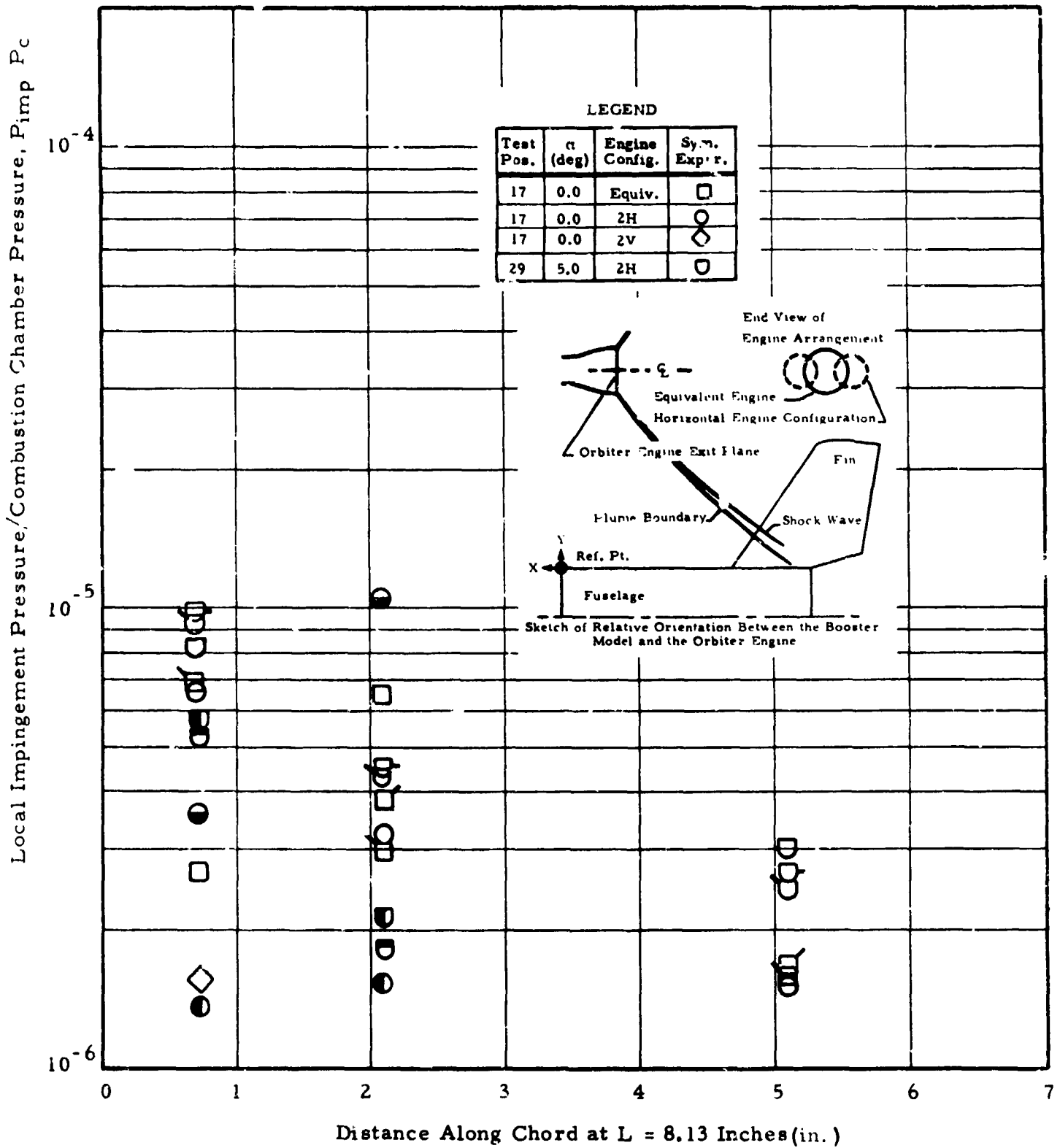


Fig. 84 - Impingement Pressure Distribution Along the Dorsal Fin Chord (Test Pos. 17 and Test Pos. 29)

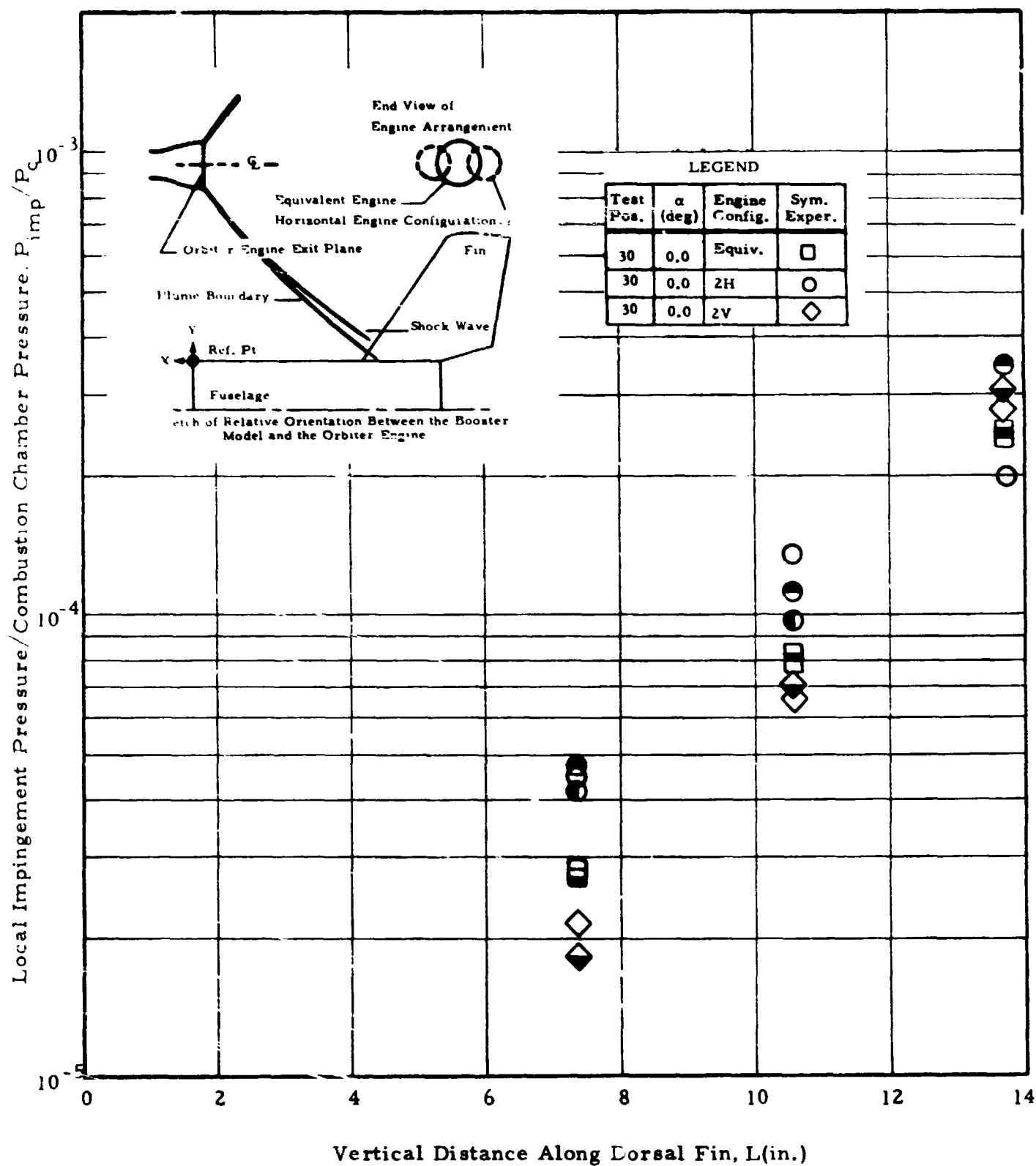


Fig. 85 - Impingement Pressure Distribution Along the Dorsal Fin Leading Edge (Test Pos. 30)

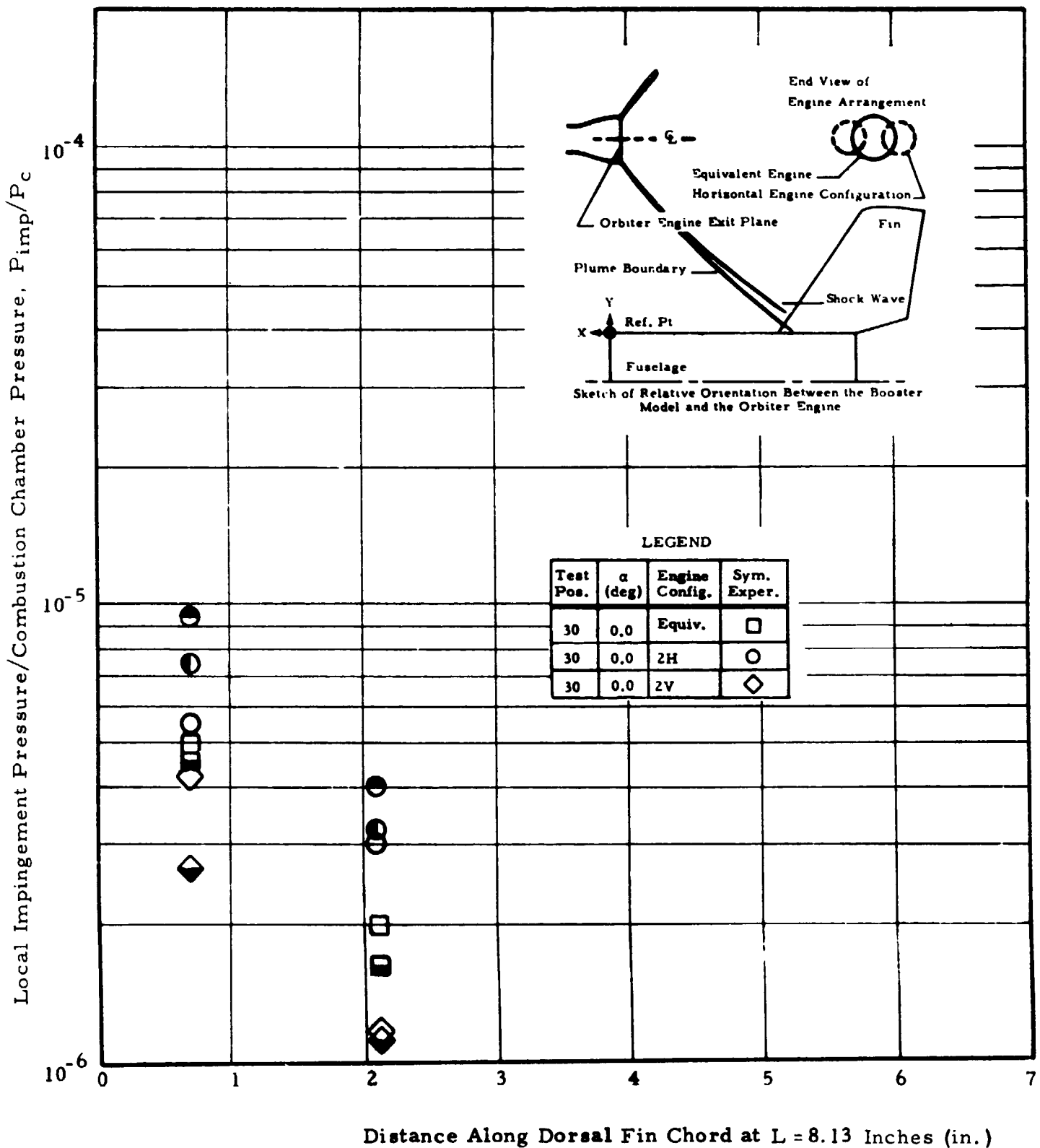


Fig. 86 - Impingement Pressure Distribution Along the Dorsal Fin Chord (Test Pos. 30)

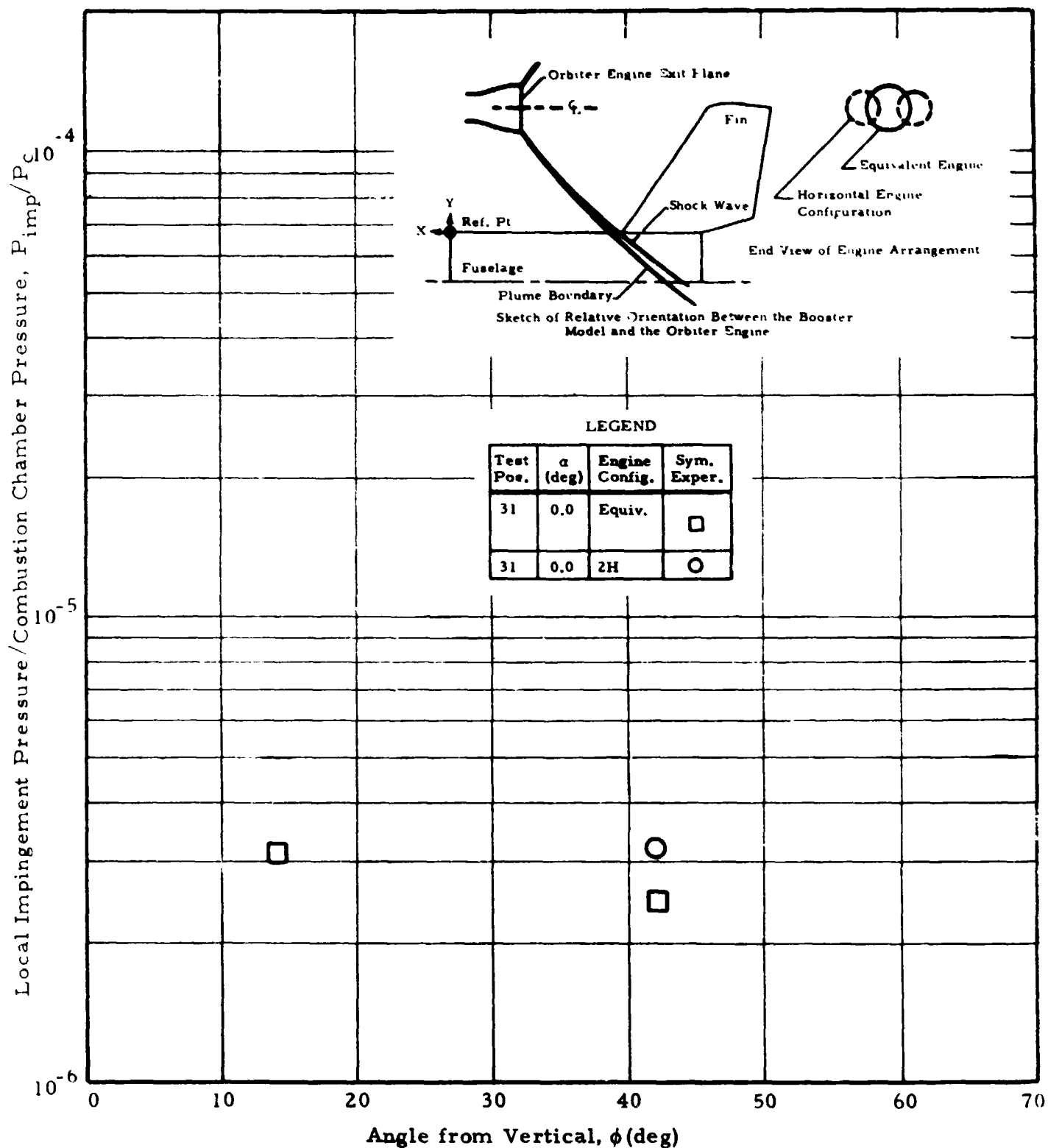


Fig. 87 - Impingement Pressure Distribution over the Booster Fuselage at Station 105.12 (Test Pos. 31)

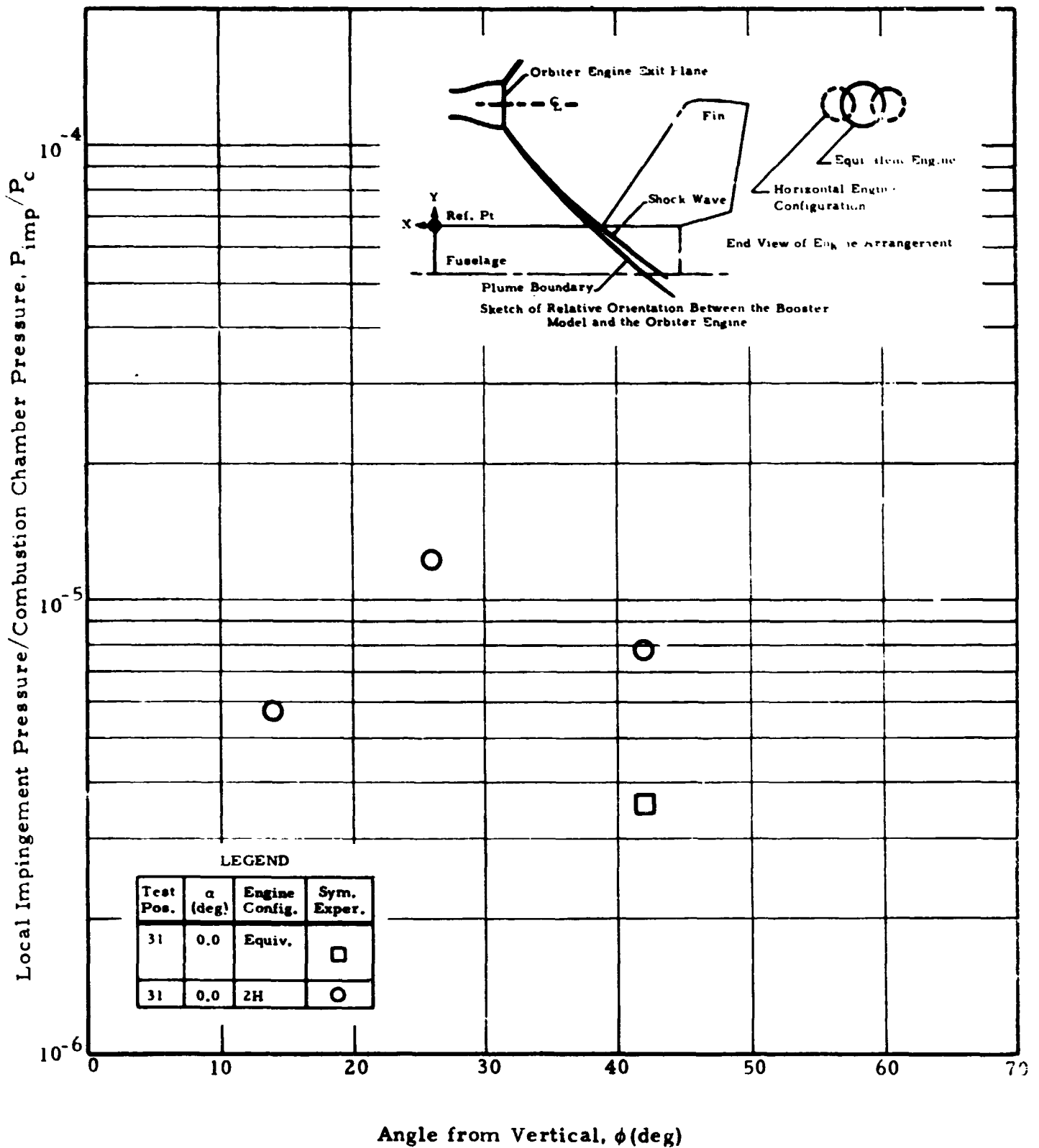


Fig. 88 - Impingement Pressure Distribution over the Booster Fuselage at Station 107.12 (Test Pos. 31)

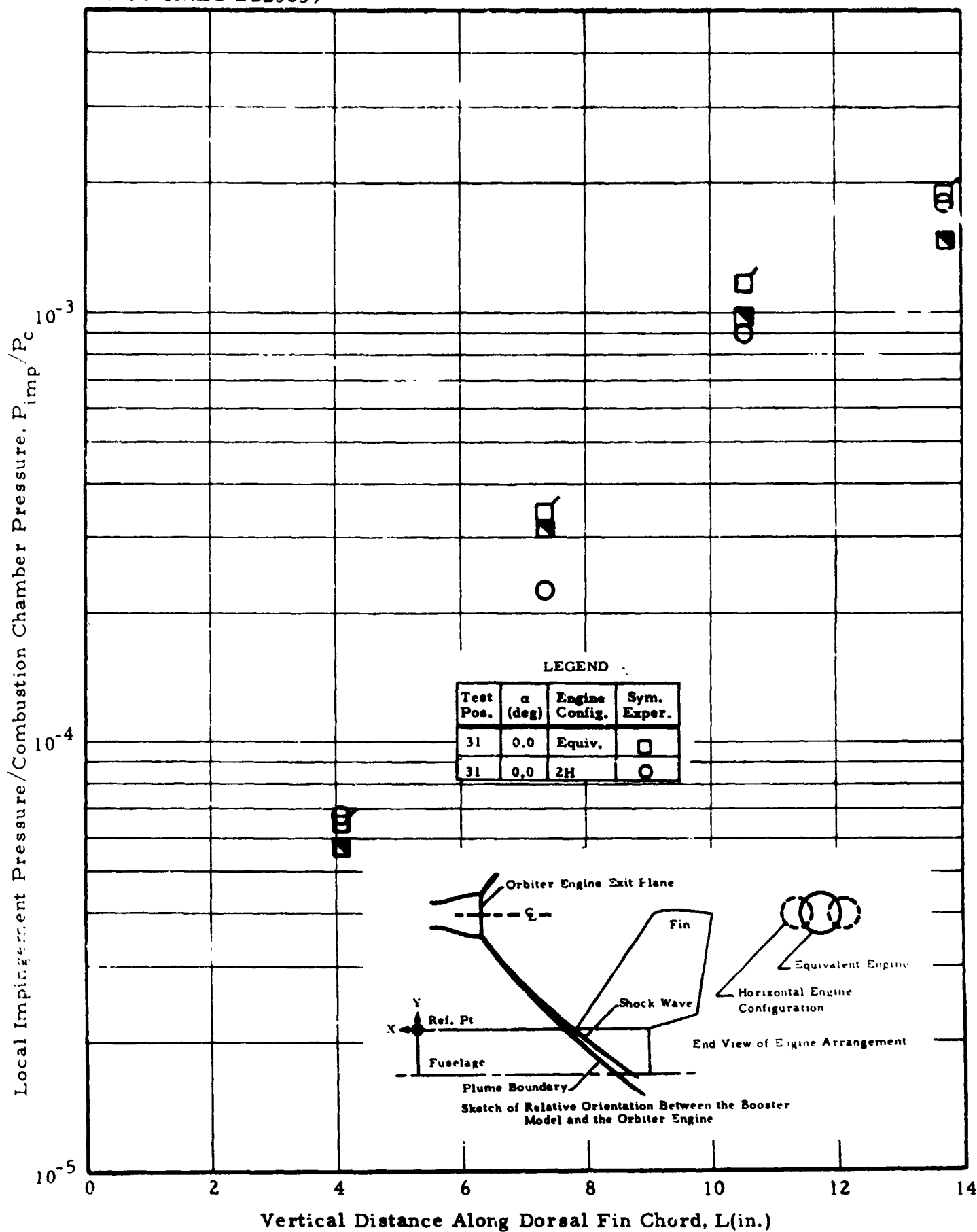


Fig. 89 - Impingement Pressure Distribution Along Dorsal Fin Leading Edge (Test Pos. 31)

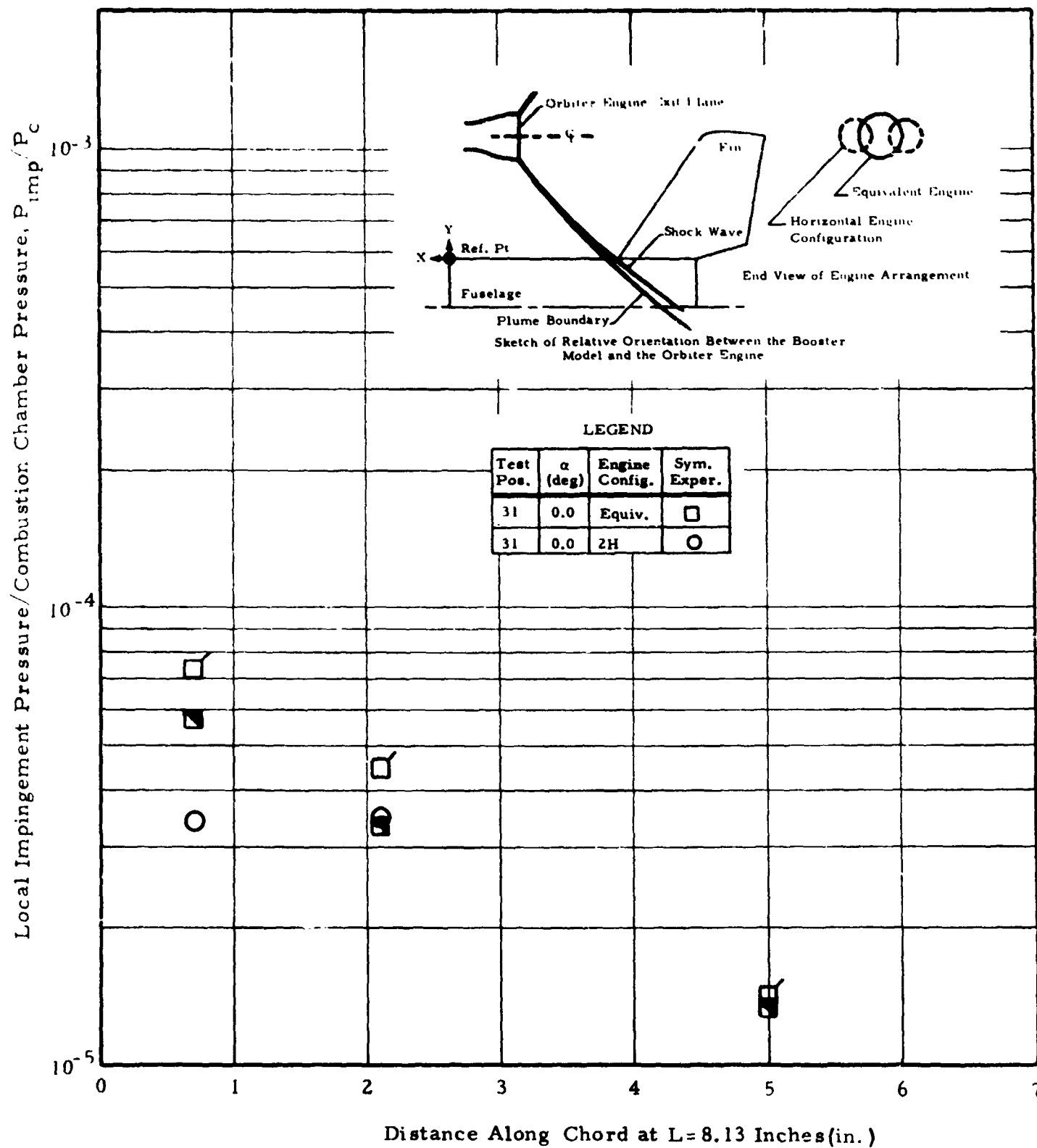


Fig. 90 - Impingement Pressure Distribution Along Dorsal Fin Chord (Test Pos. 31)

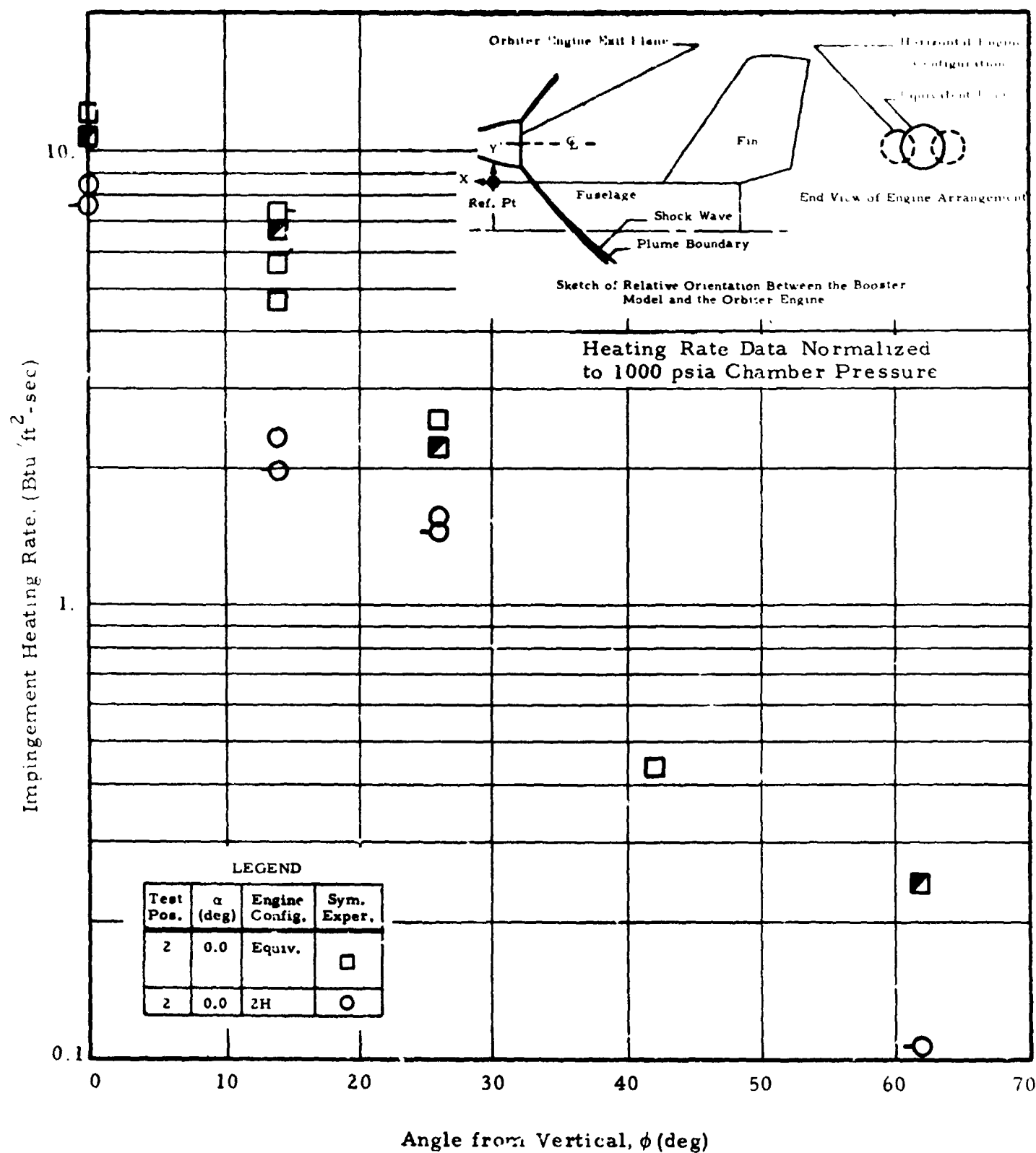


Fig. 91 - Heat Transfer Distribution over Fuselage at Station 85.62 (Test Pos. 2)

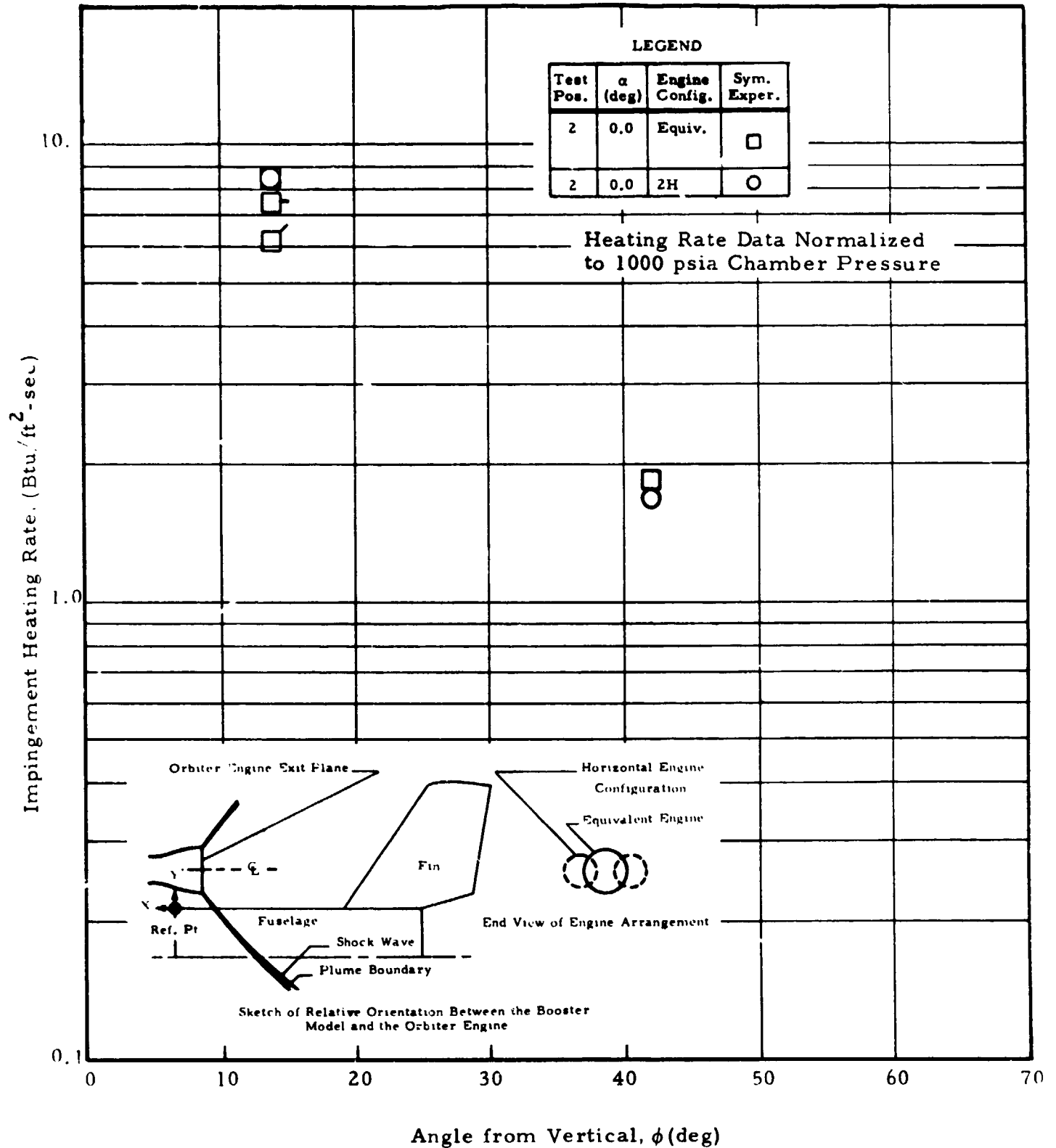


Fig. 92 - Heat Transfer Distribution over Fuselage at Station 94.62 (Test Pos. 2)

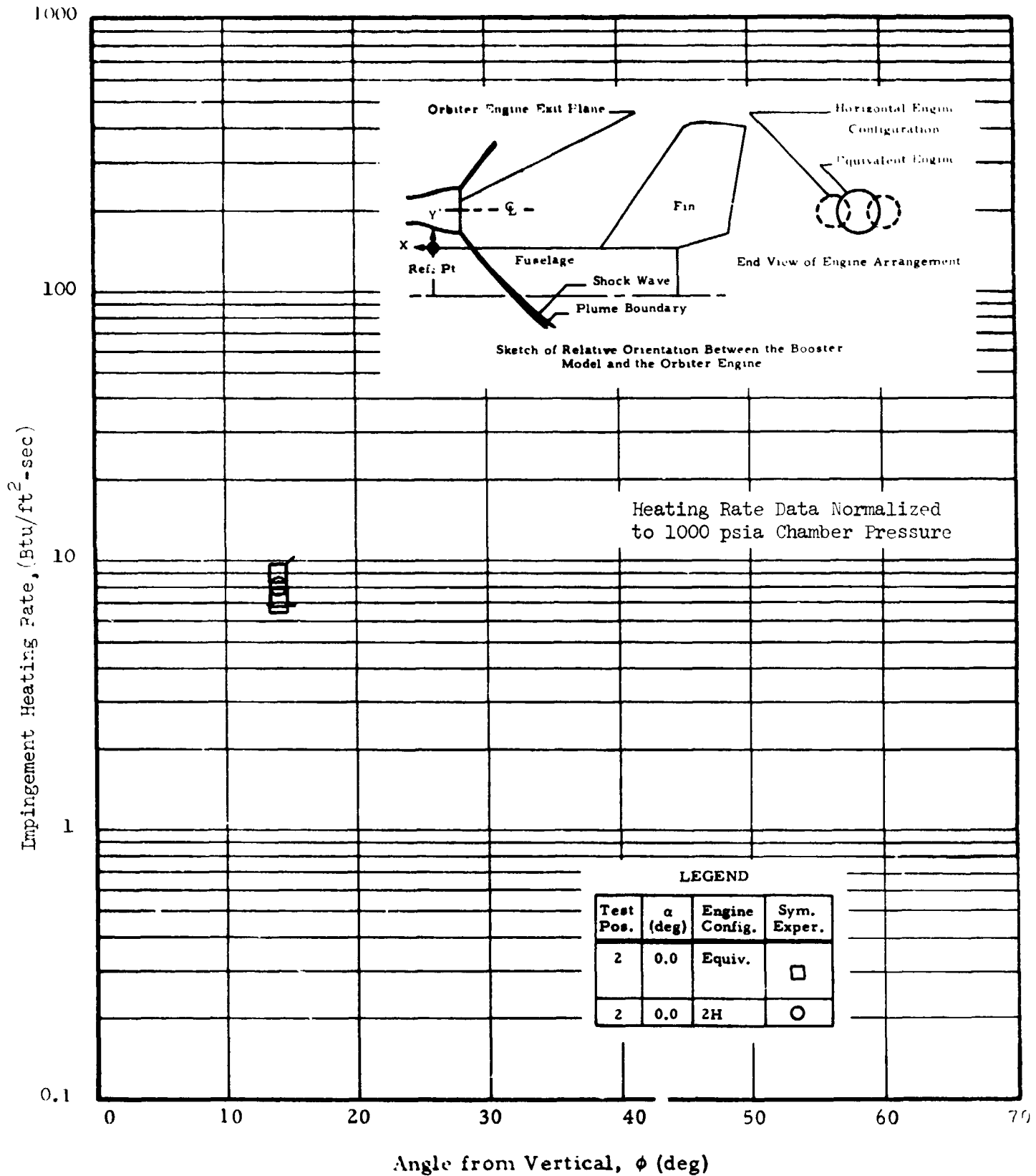


Fig. 93 - Heat Transfer Distribution over Fuselage at Station 100.62 (Test Pos. 2)

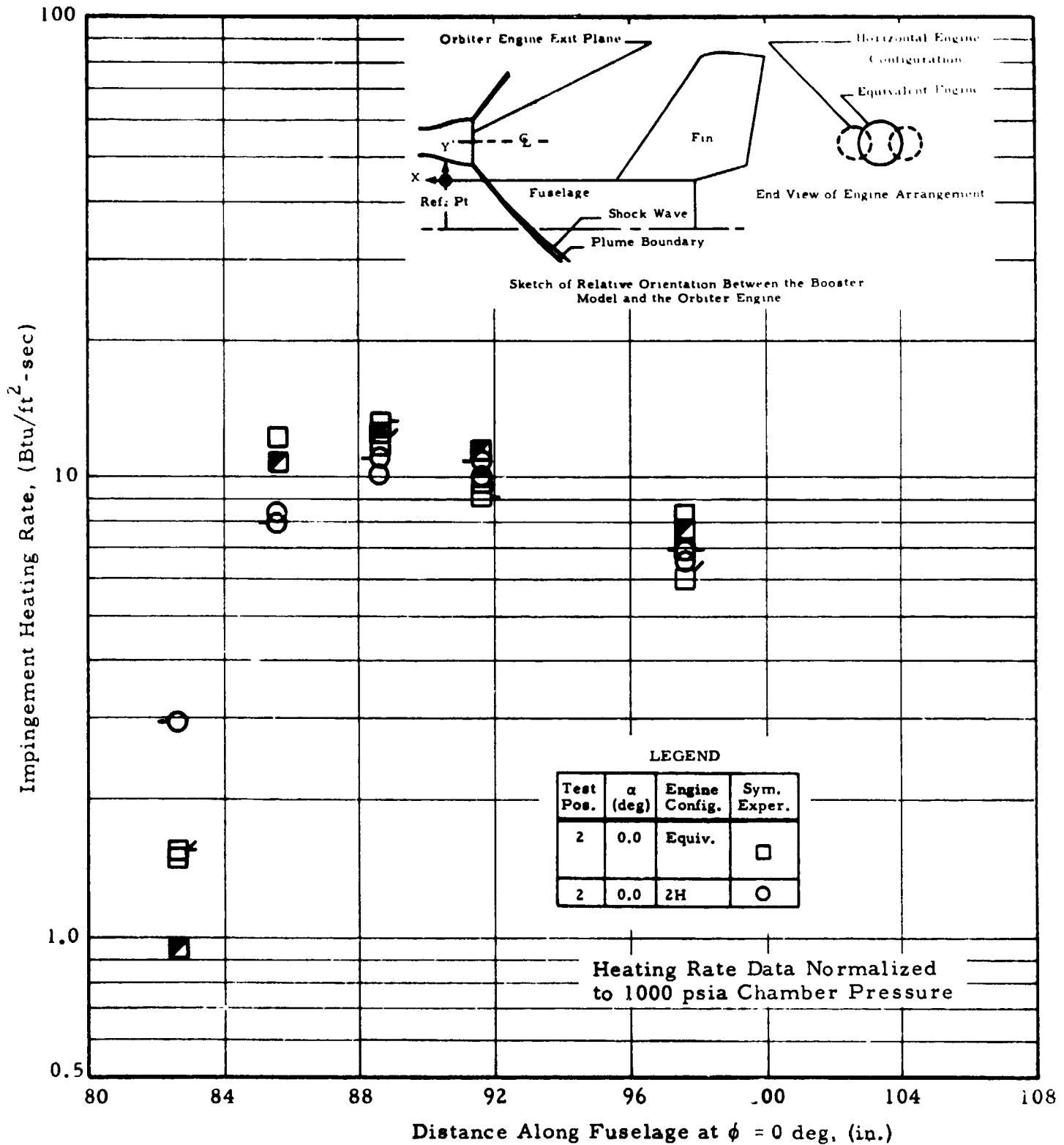


Fig. 94 - Heat Transfer Distribution Along Fuselage Stagnation Line (Test Pos. 2)

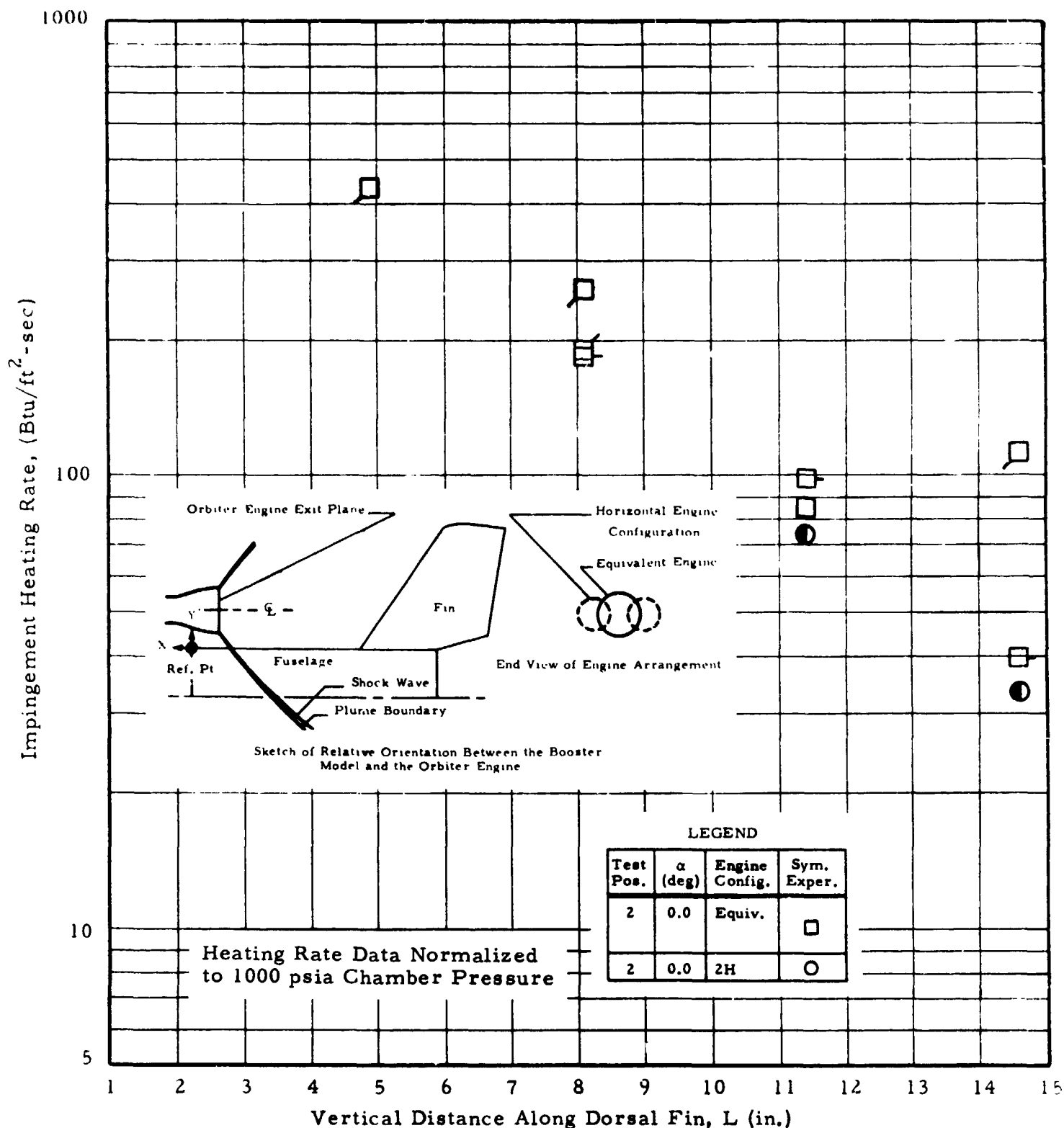


Fig. 95 - Heat Transfer Distribution Along Dorsal Fin Leading Edge (Test Pos. 2)

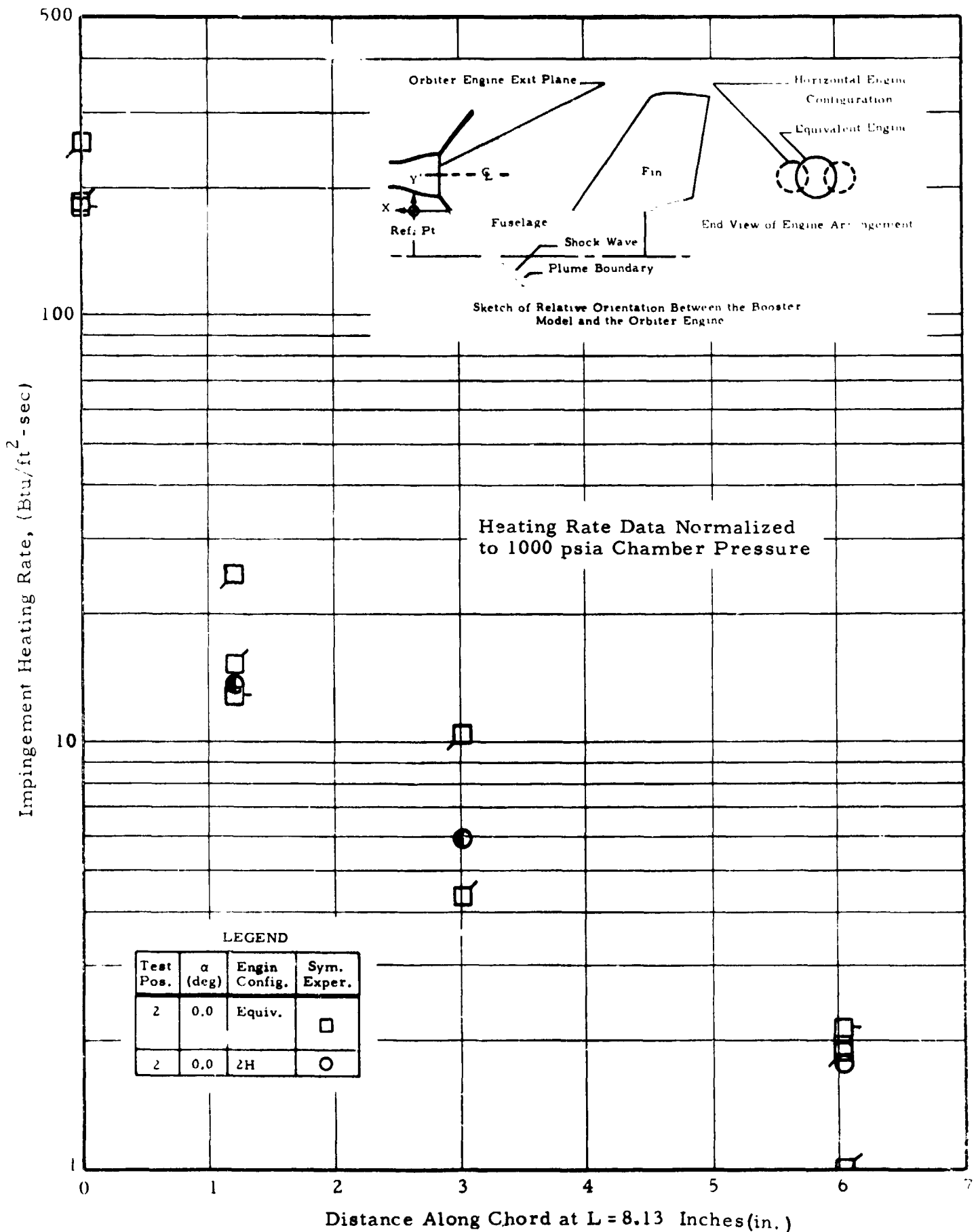


Fig. 96 - Heat Transfer Distribution Along Dorsal Fin Chord (Test Pos. 2)

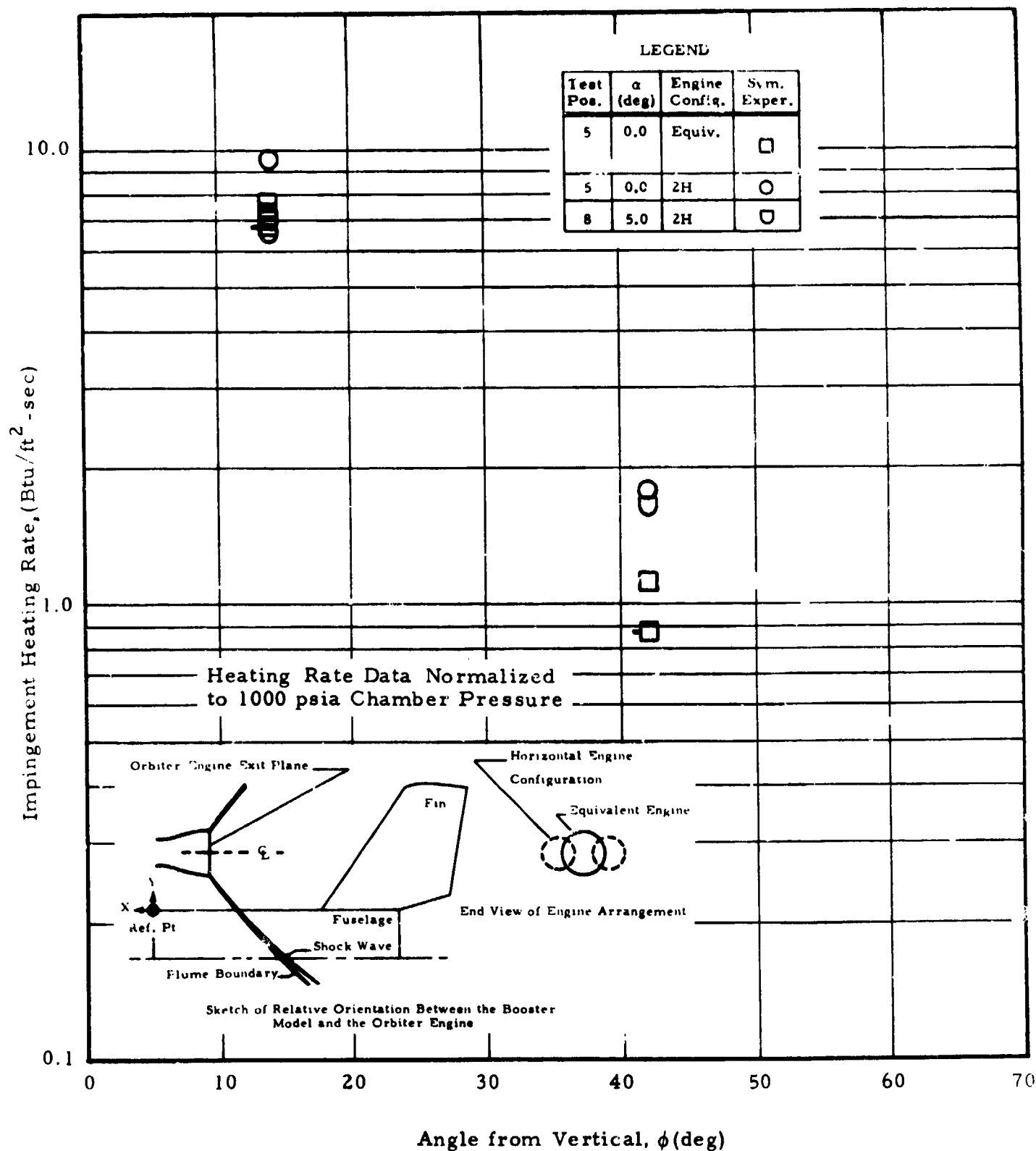


Fig. 97 - Heat Transfer Distribution over Fuselage at Station 94.62 (Test Pos. 5 and 8)

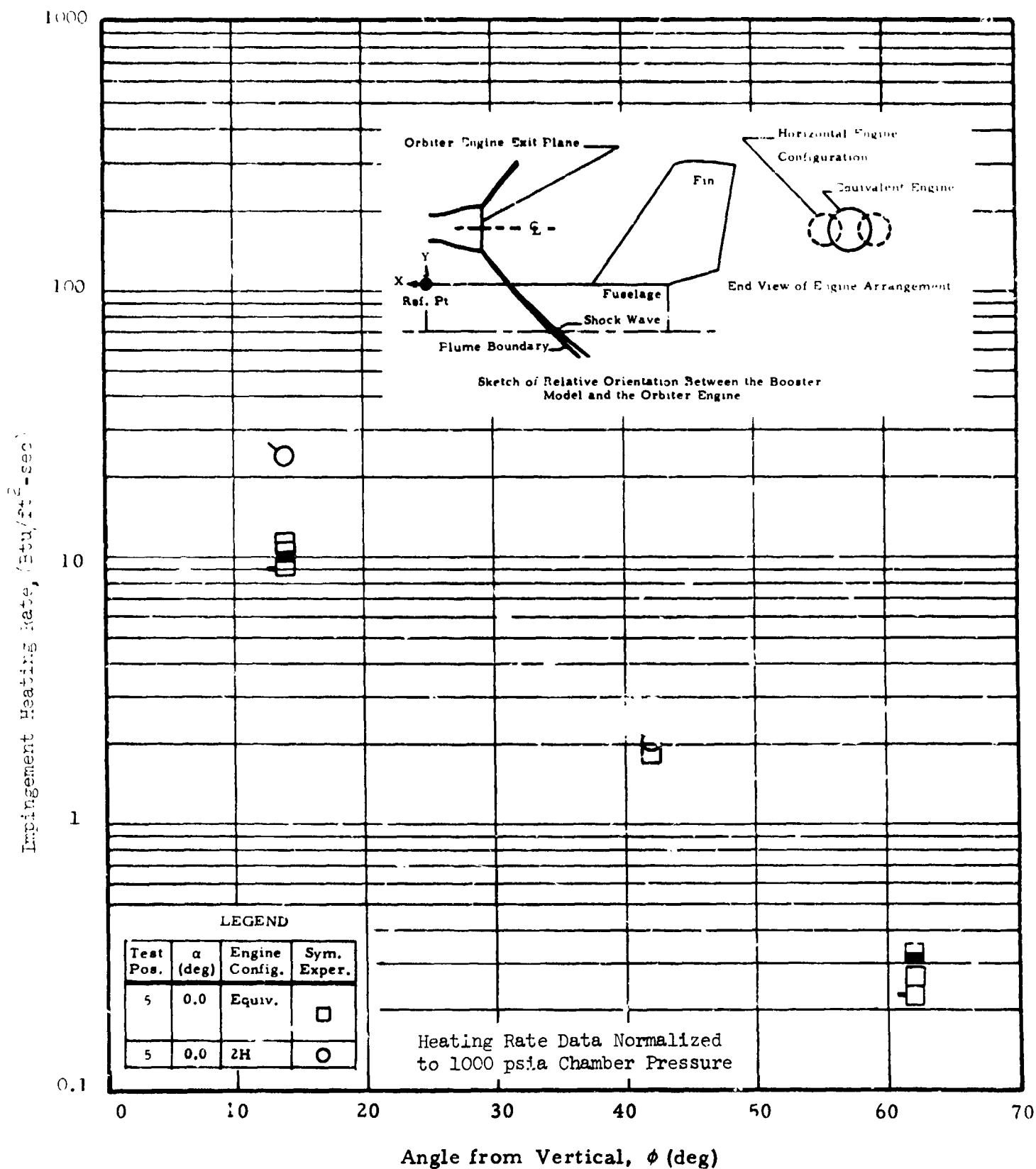


Fig. 98 - Heat Transfer Distribution over Fuselage at Station 100.62 (Test Pos. 5)

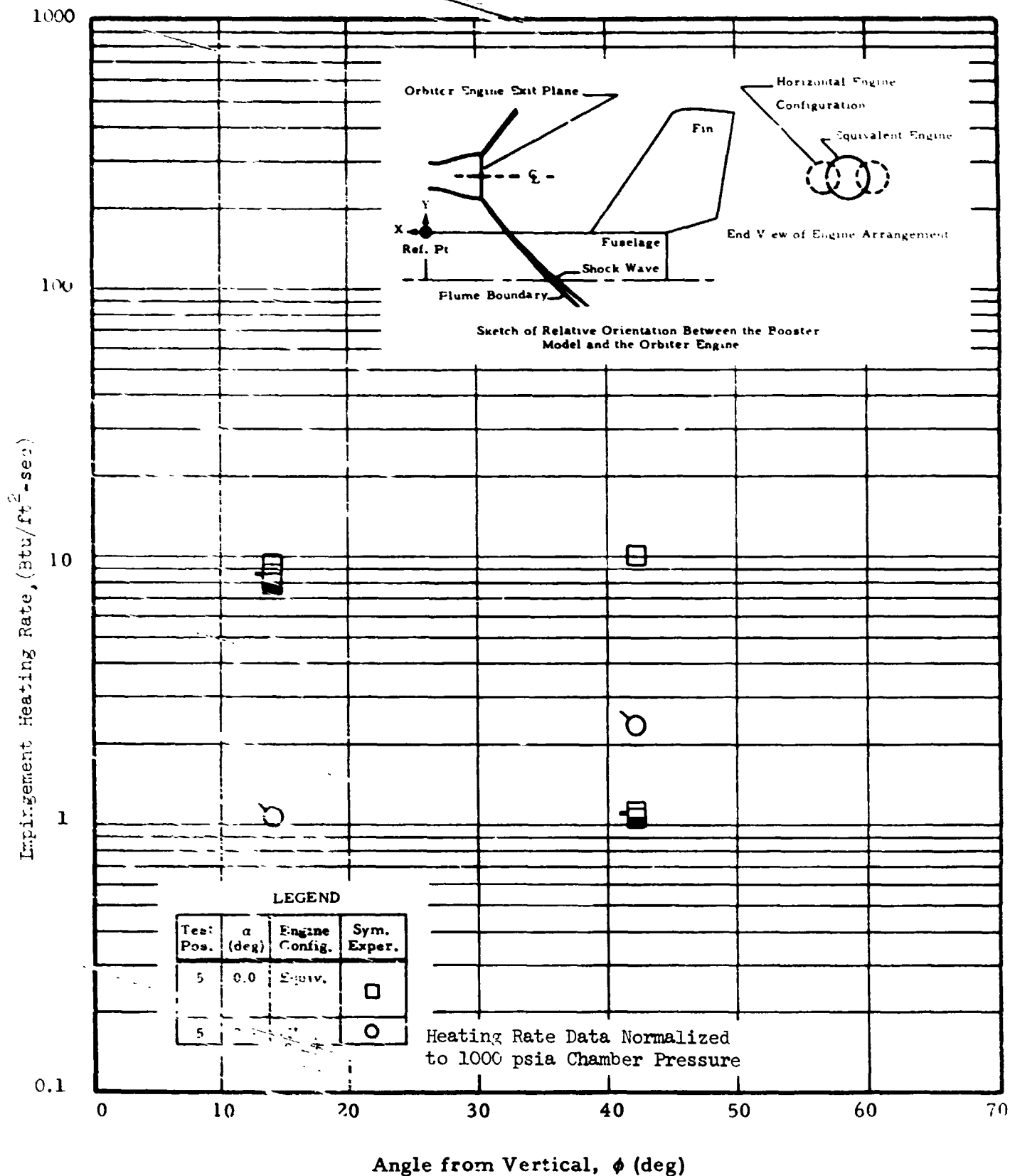


Fig. 22 - Heat Transfer Distribution over Fuselage at Station 103.62 (Test Pos. 5)

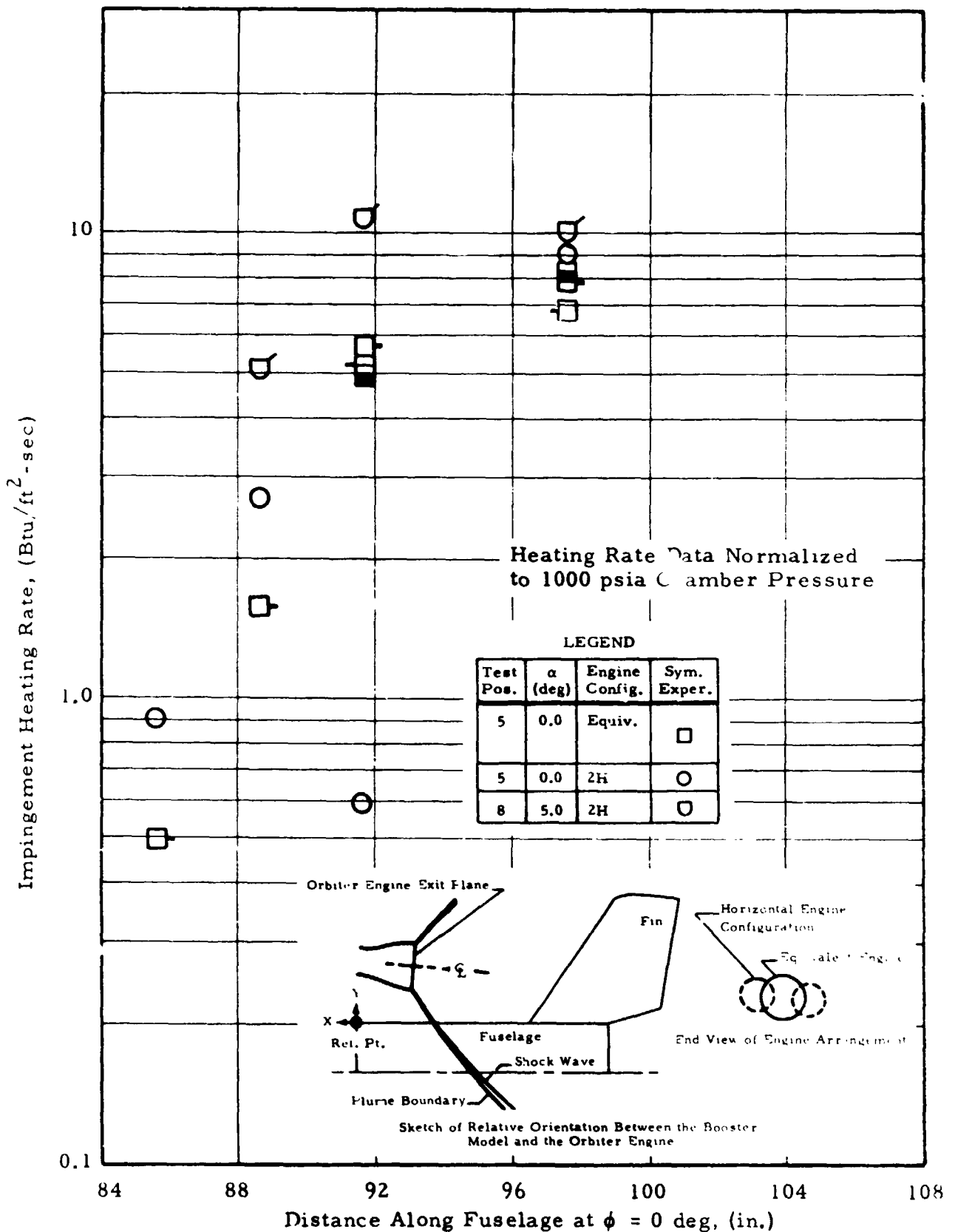


Fig. 100 - Heat Transfer Distribution Along Fuselage Stagnation Line (Test Positions 5 and 8)

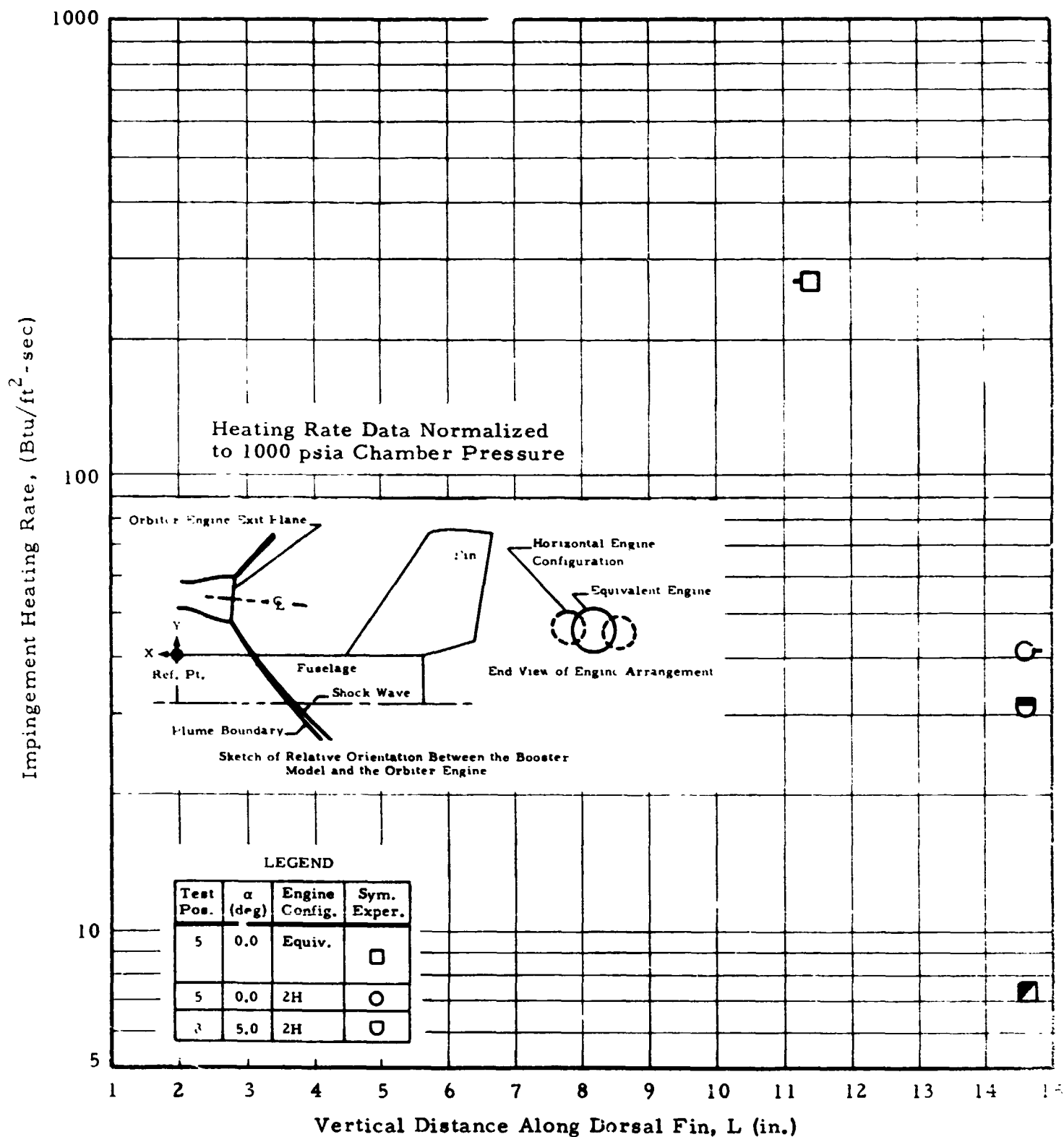


Fig. 101 - Heat Transfer Distribution Along Dorsal Fin Leading Edge  
(Test Positions 5 and 8)

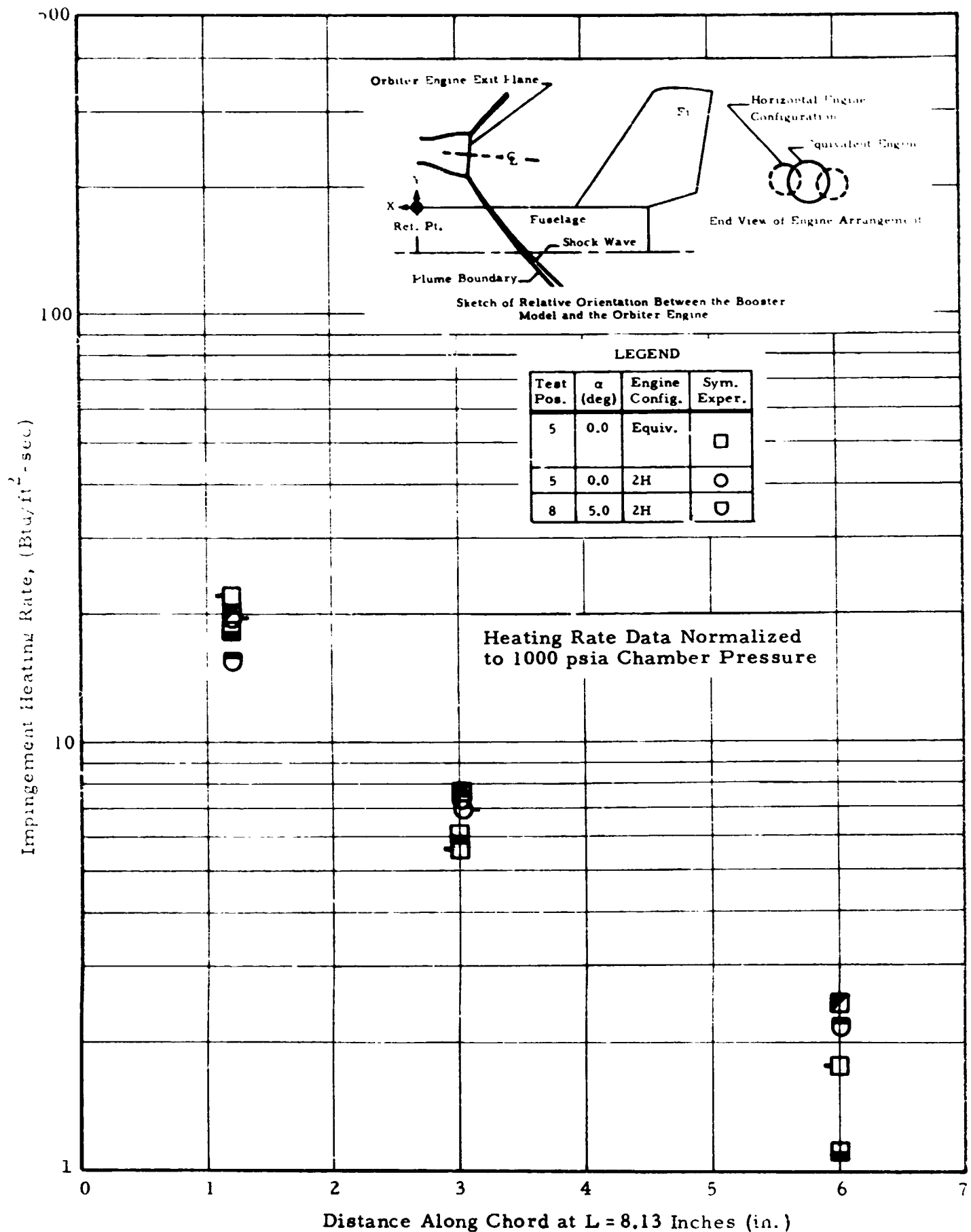


Fig. 102 - Heat Transfer Distribution Along Dorsal Fin Chord (Test Pos. 5 and 8)

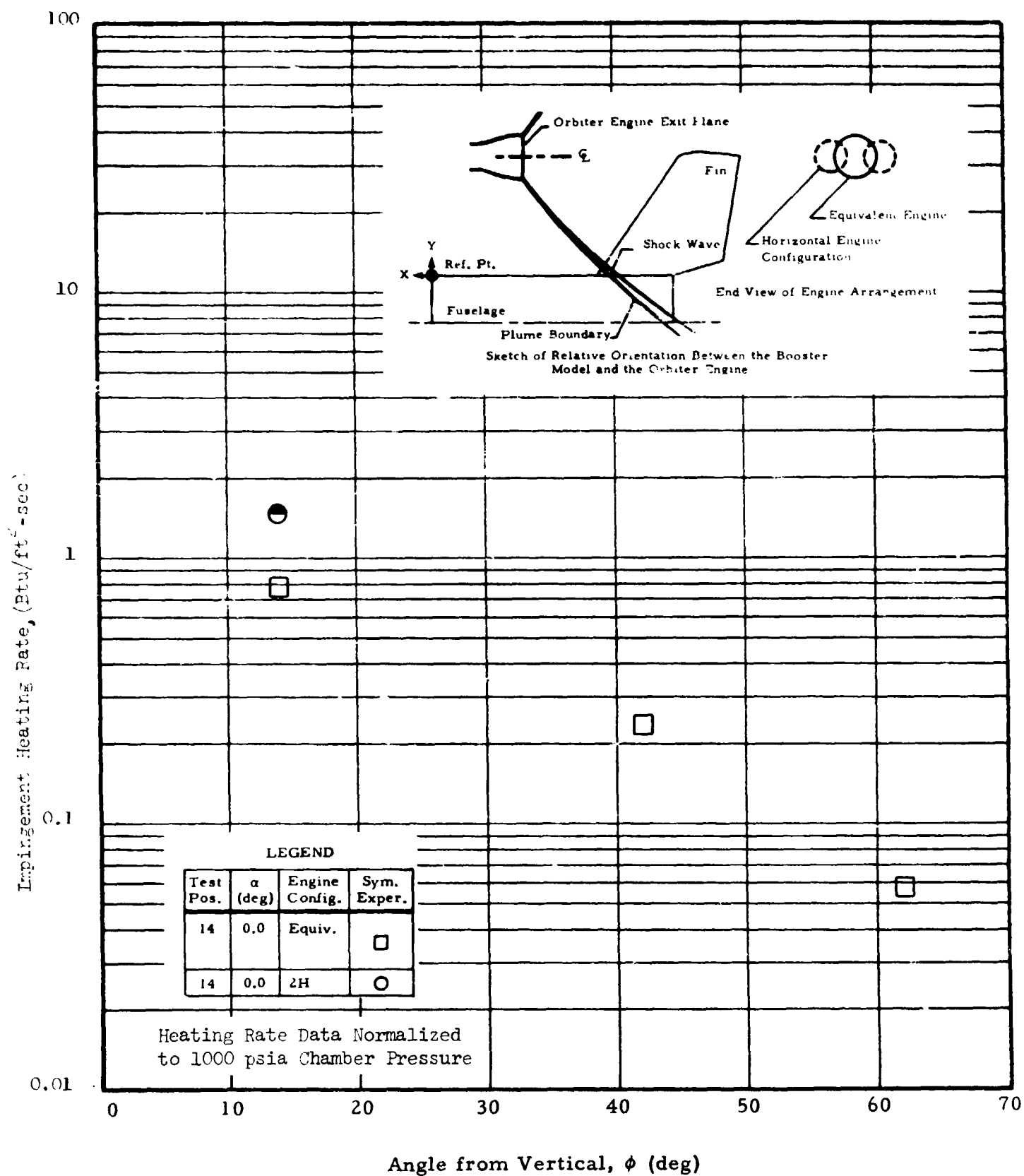


Fig. 103 - Heat Transfer Distribution over Fuselage at Station 100.62 (Test Pos. 14)

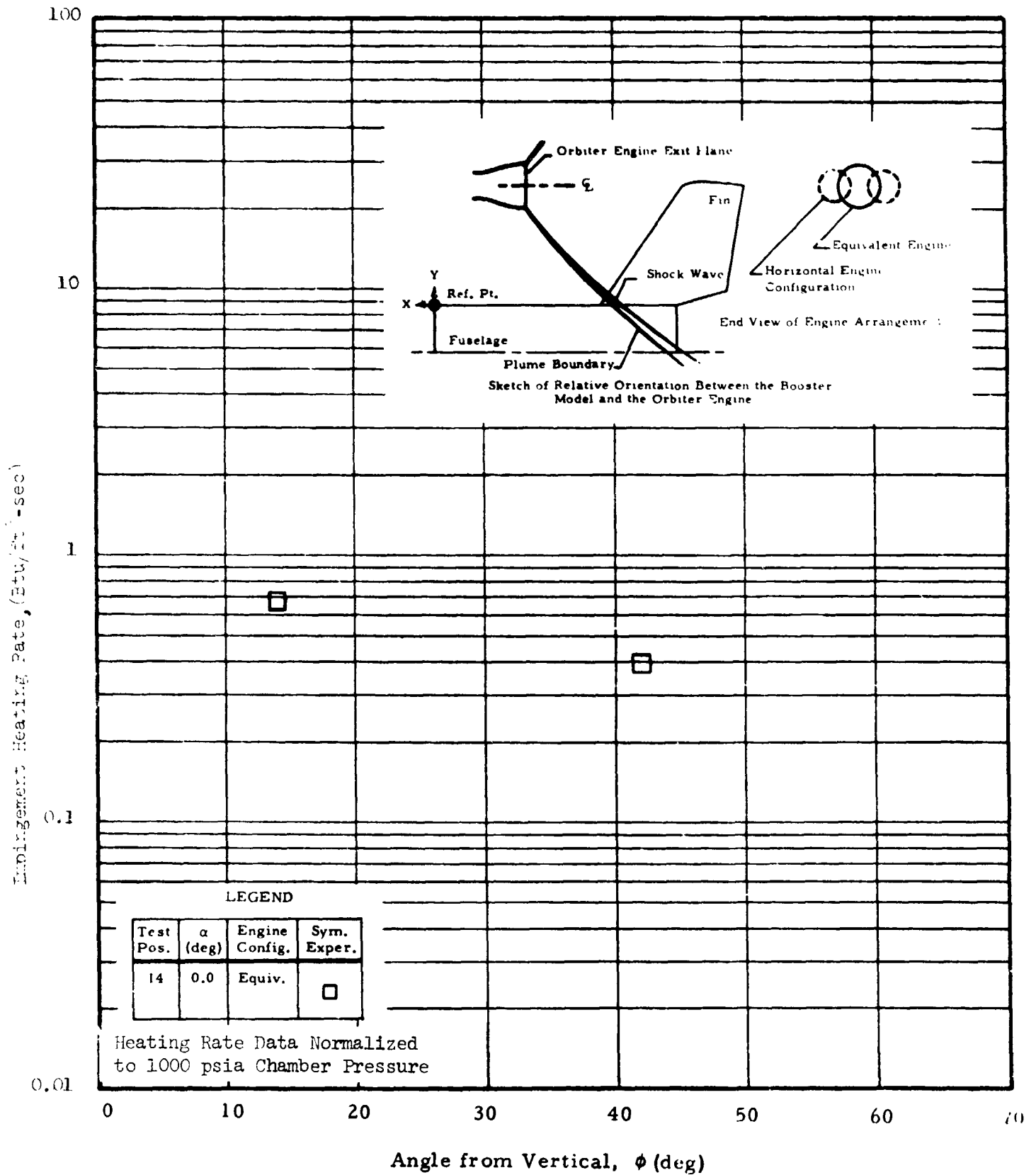


Fig. 104 - Heat Transfer Distribution over Fuselage at Station 103.62 (Test Pos. 14)

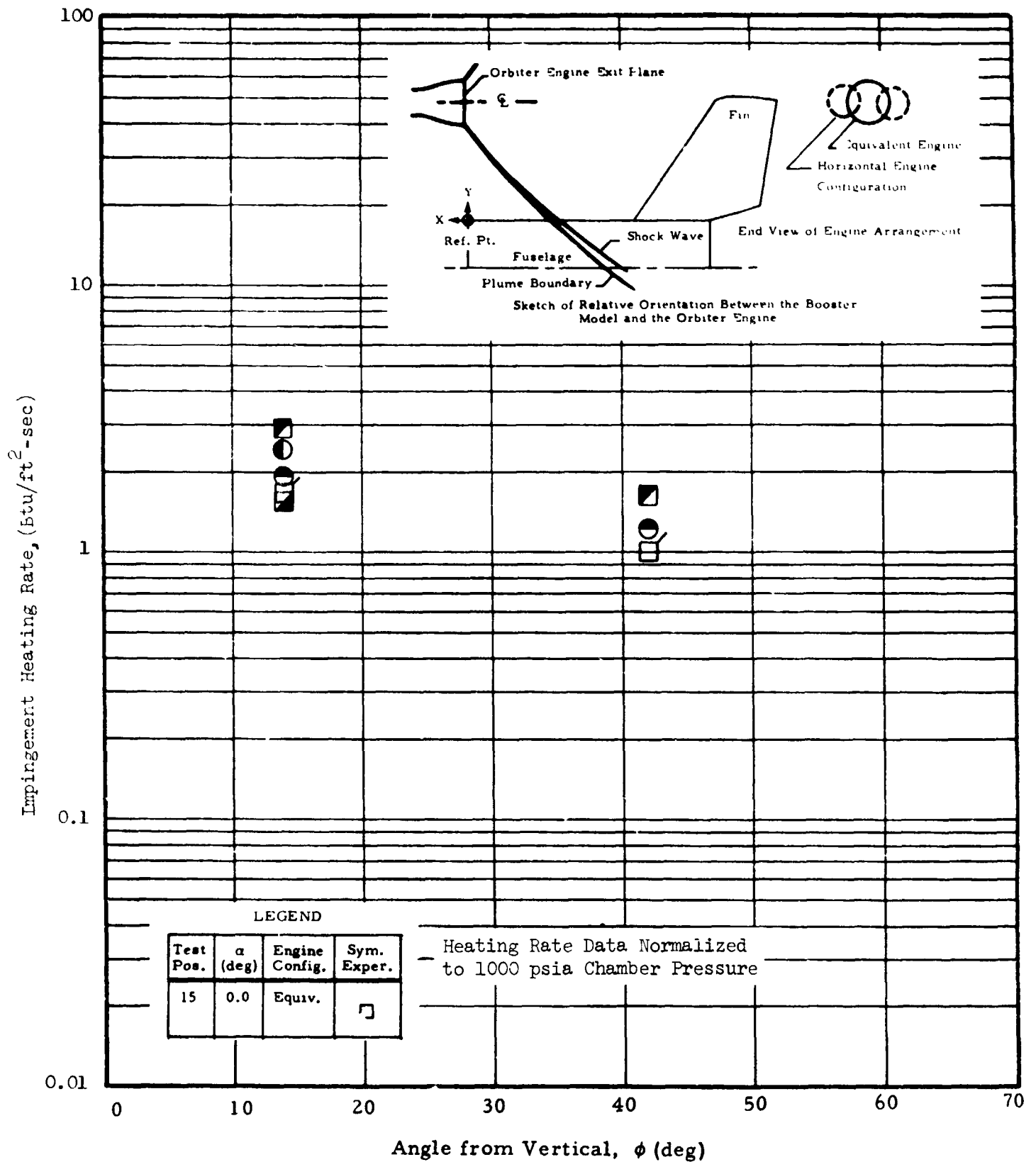


Fig. 105 - Heat Transfer Distribution over Fuselage at Station 103.62 (Test Pos. 15)

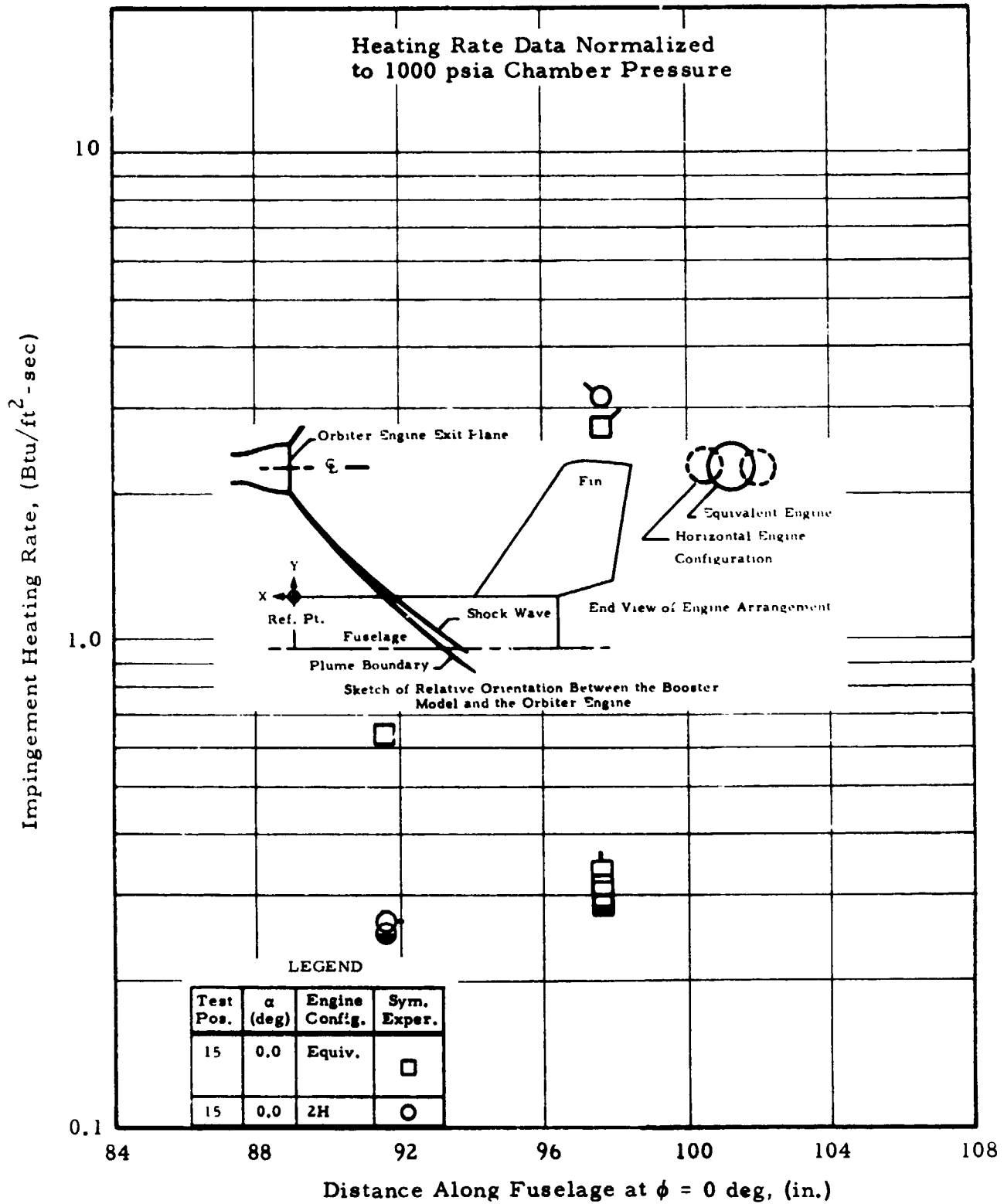


Fig. 106 - Heat Transfer Distribution Along Fuselage Stagnation Line (Test Pos. 15)

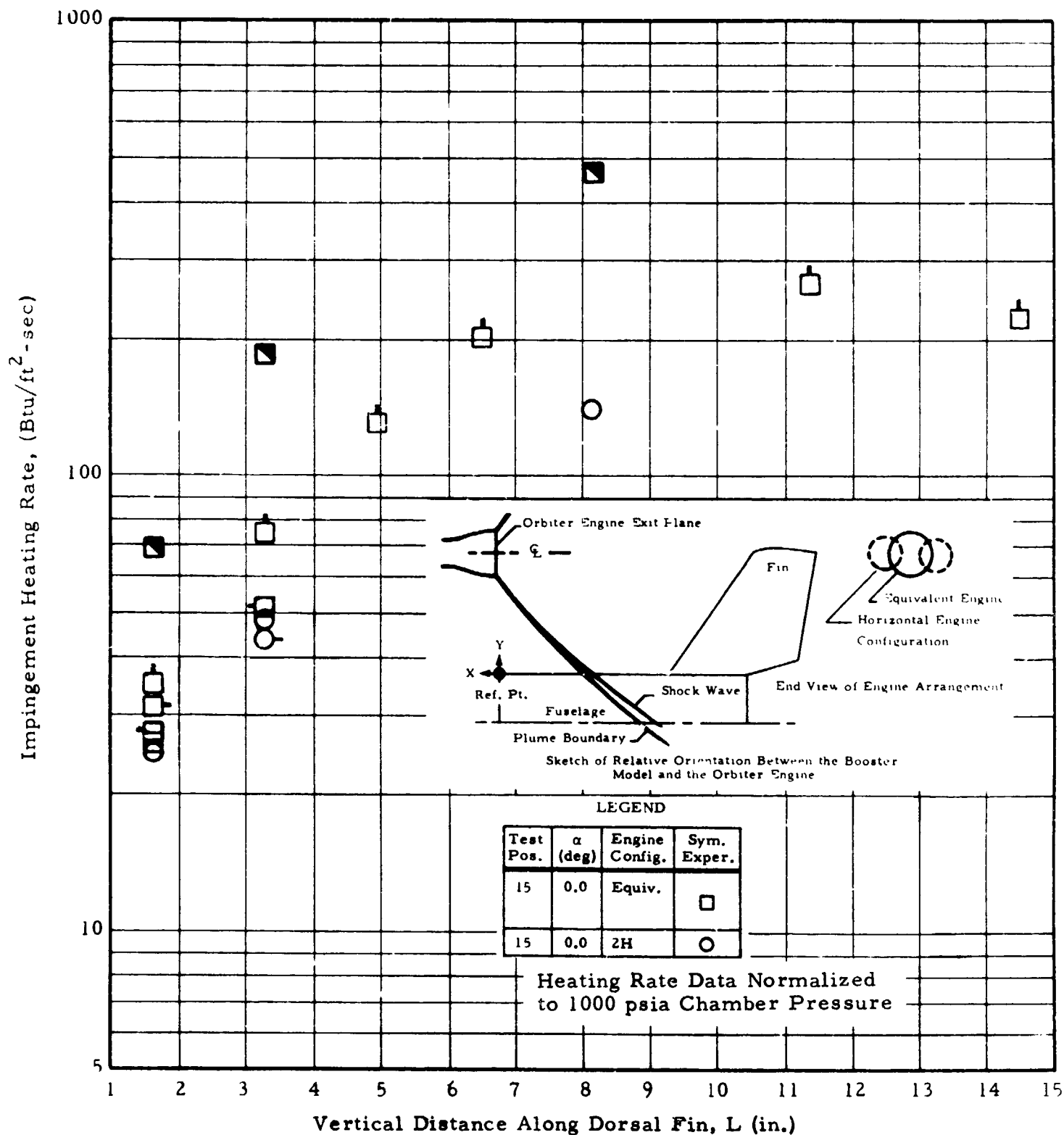


Fig 107 - Heat Transfer Distribution Along Dorsal Fin Leading Edge (Test Pos. 15)

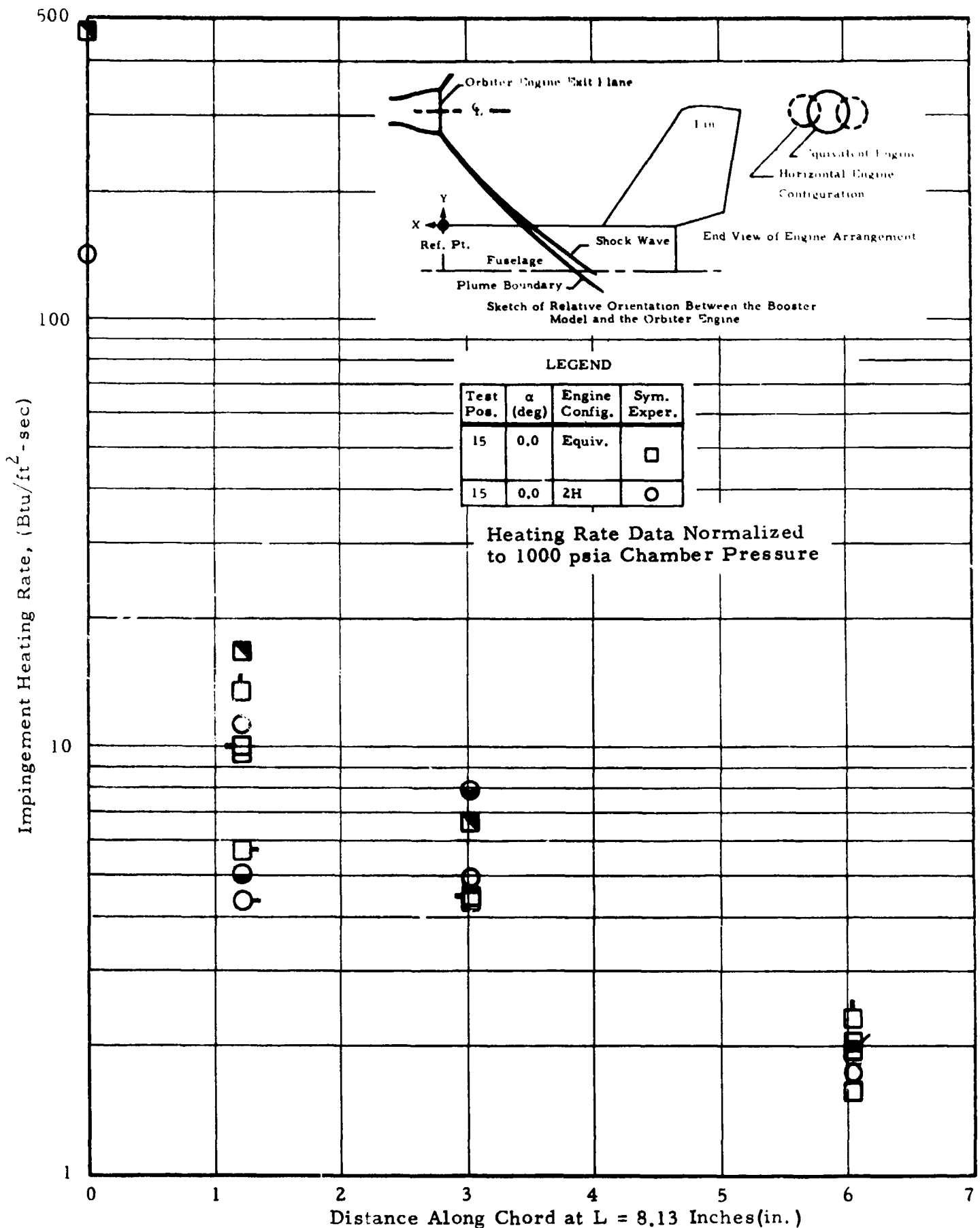


Fig. 108 - Heat Transfer Distribution Along Dorsal Fin Chord (Test Pos. 15)

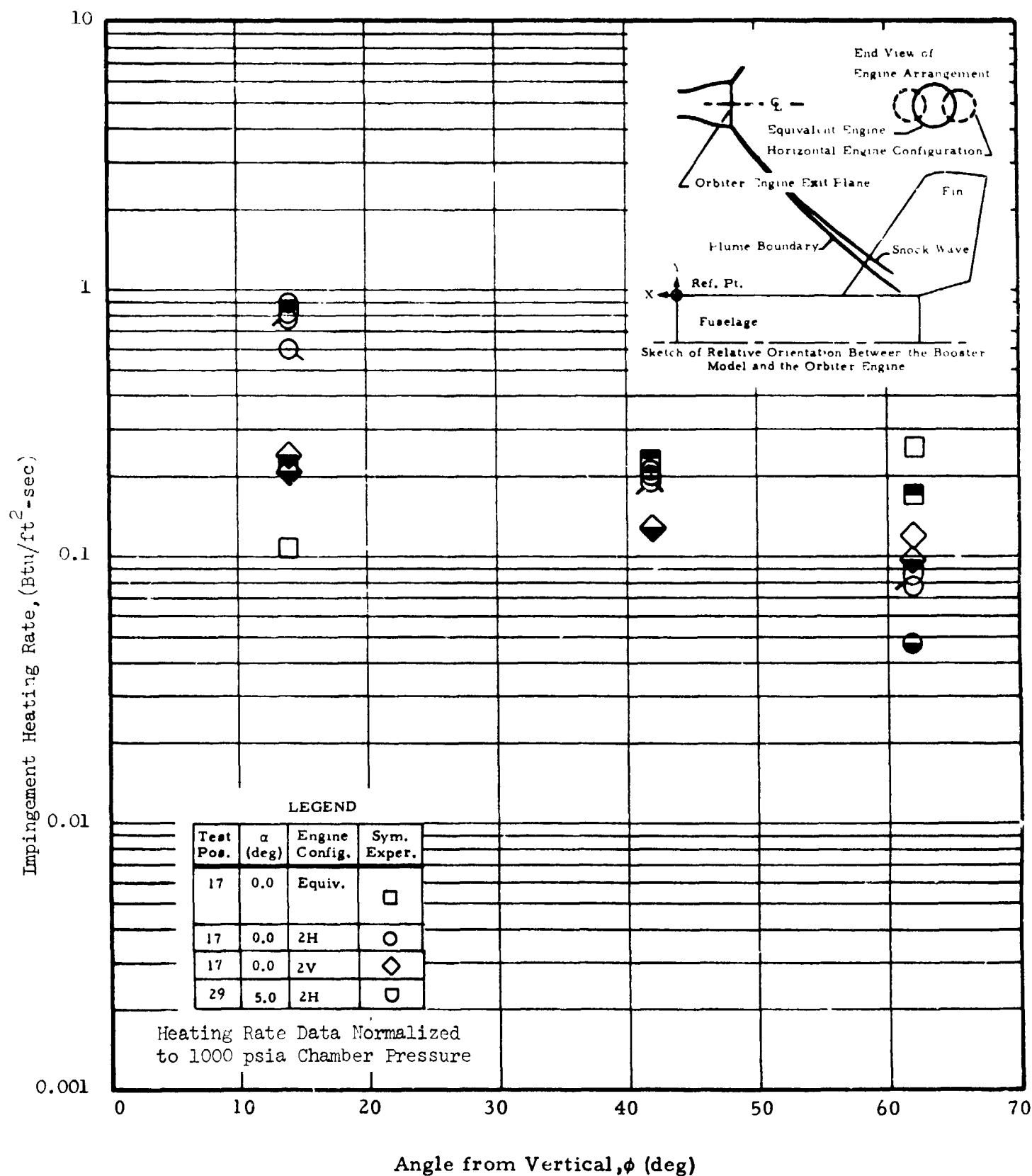


Fig. 109 - Heat Transfer Distribution over Fuselage at Station 100.62 (Test Pos. 17 and 29)

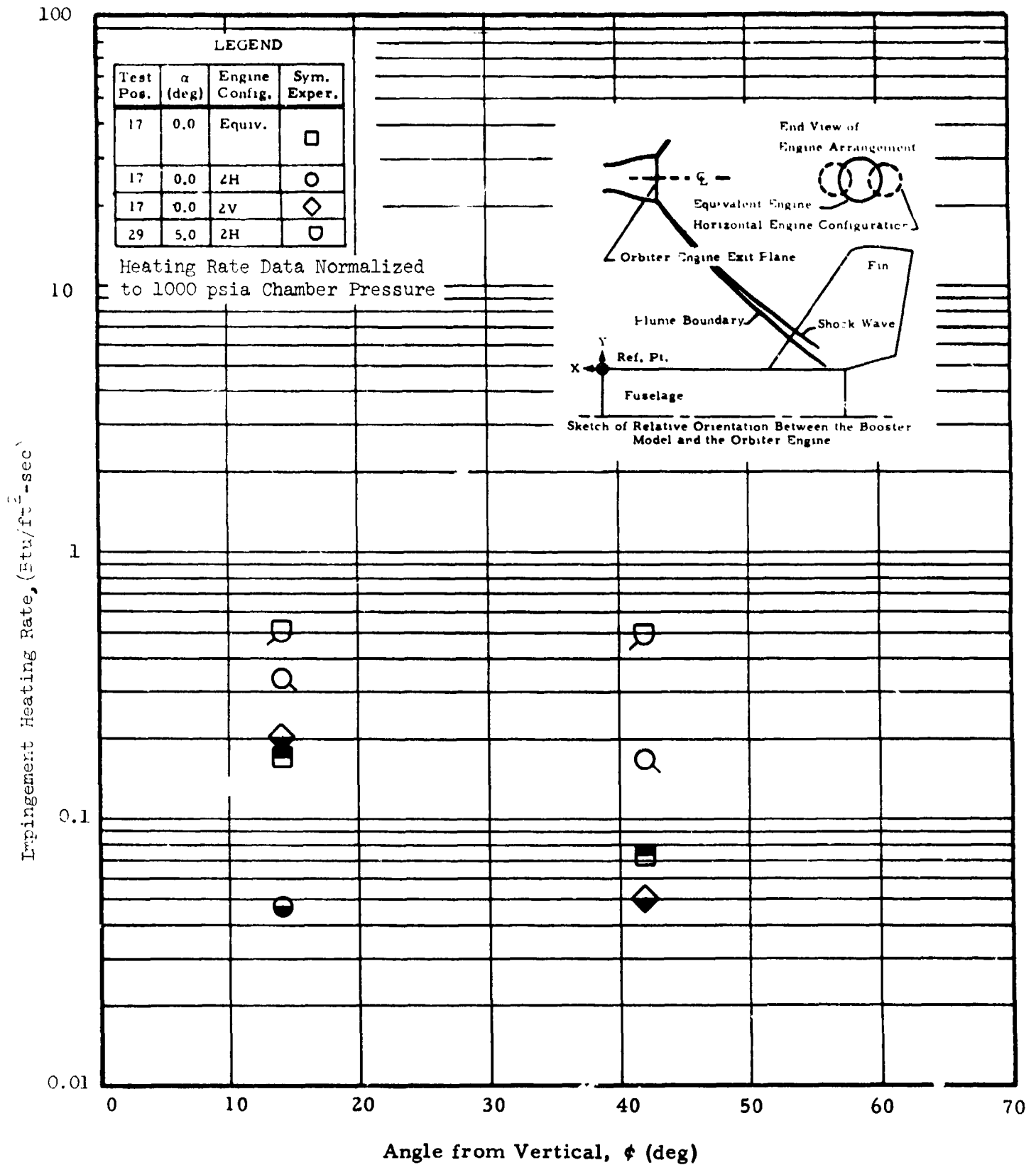


Fig. 110 - Heat Transfer Distribution over Fuselage at Station 103.62 (Test Pos. 17 and 29)

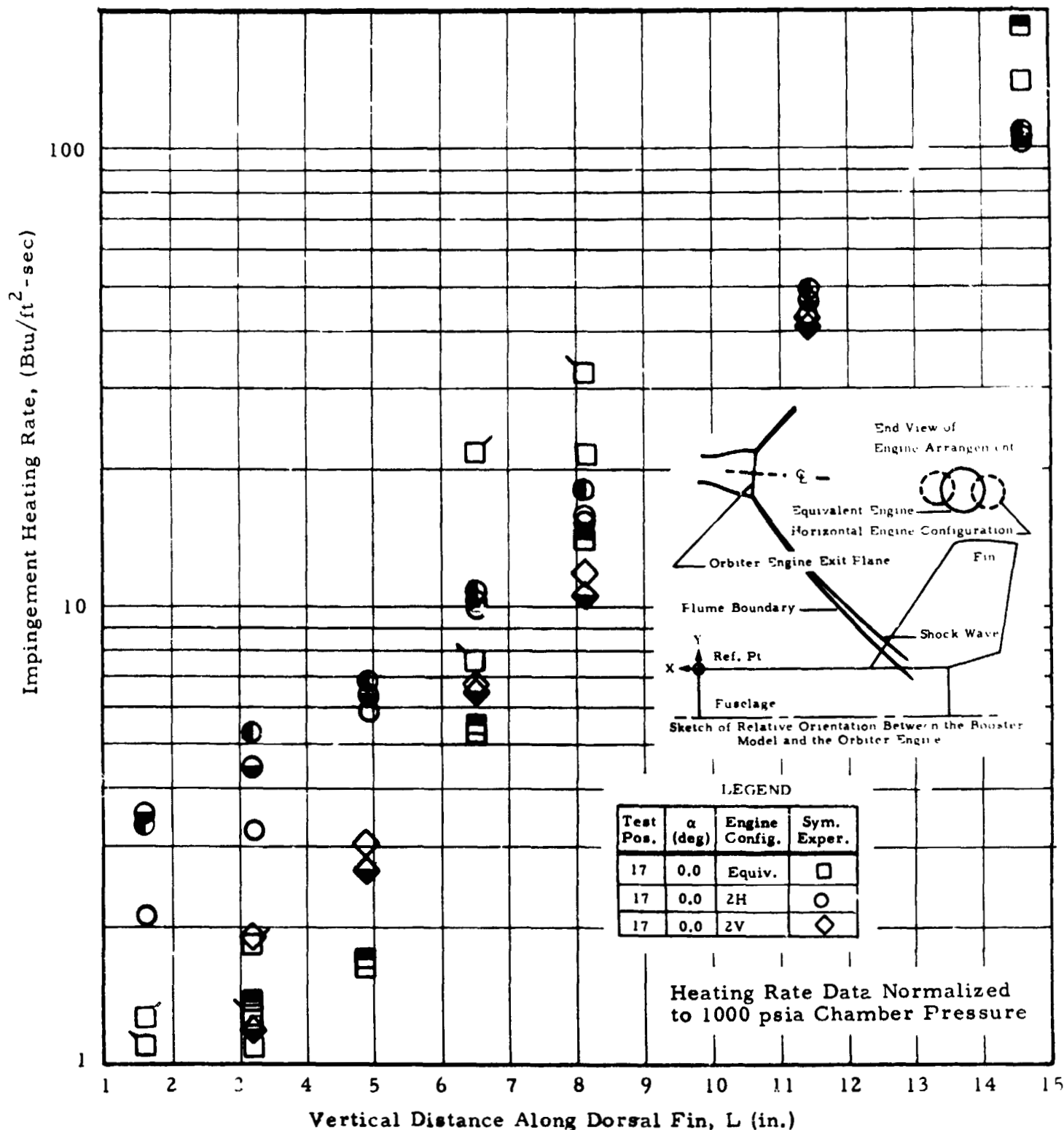


Fig. 111 - Heat Transfer Distribution Along Dorsal Fin Leading Edge (Test Pos. 17)

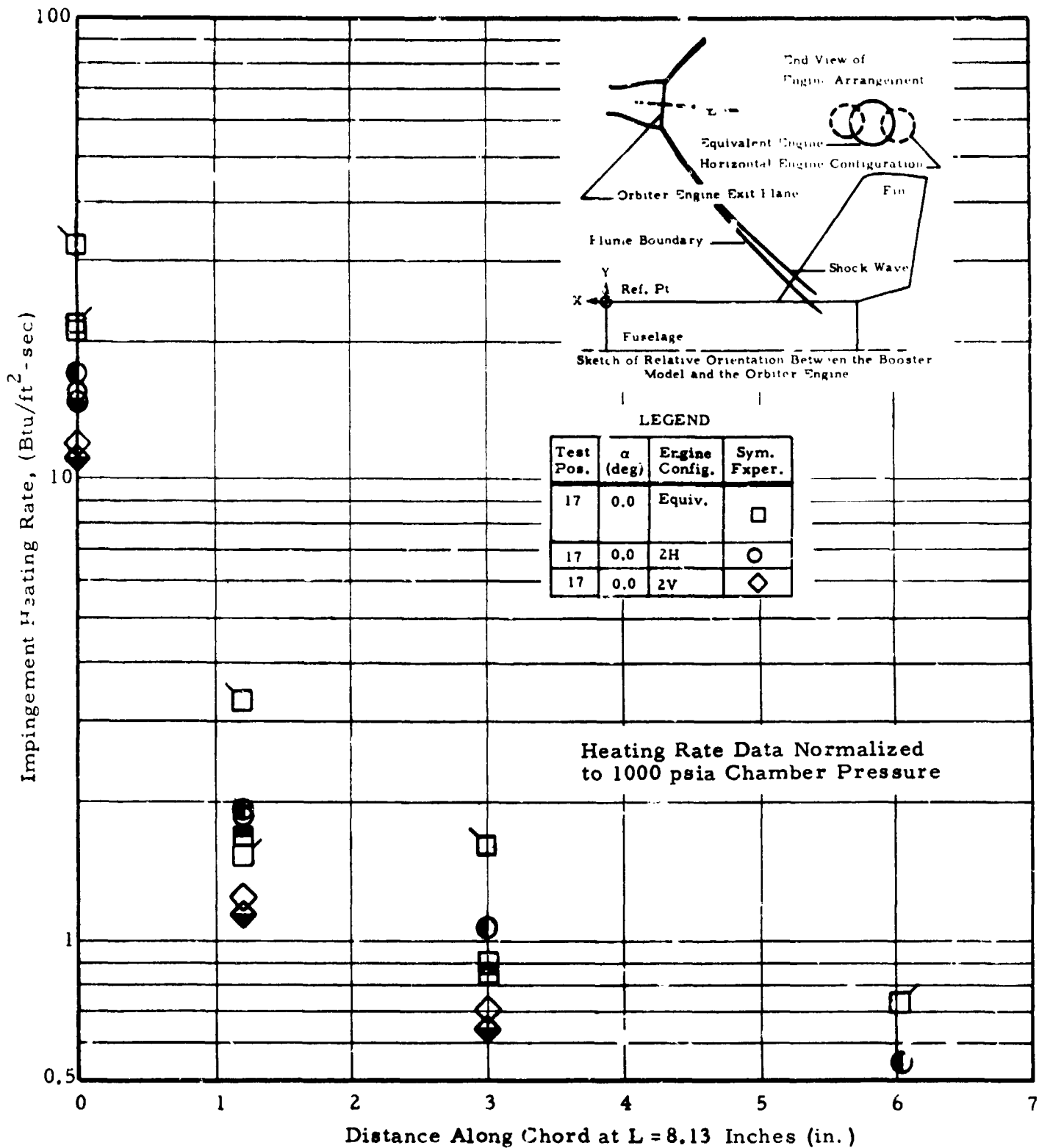


Fig. 112 - Heat Transfer Distribution Along Dorsal Fin Chord (Test Pos. 17)

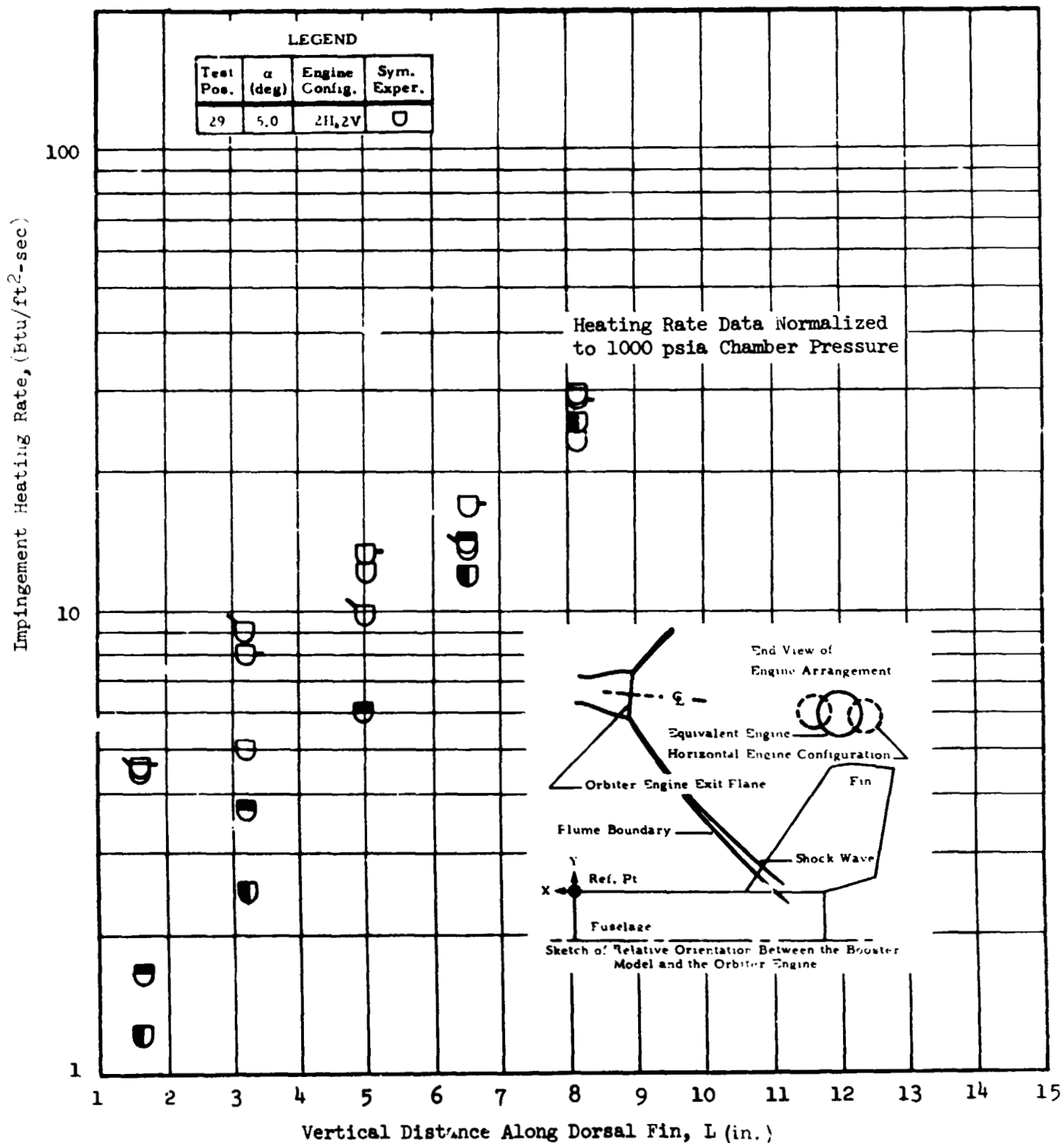


Fig. 113 - Heat Transfer Distribution Along Dorsal Fin Leading Edge (Test Pos. 29)

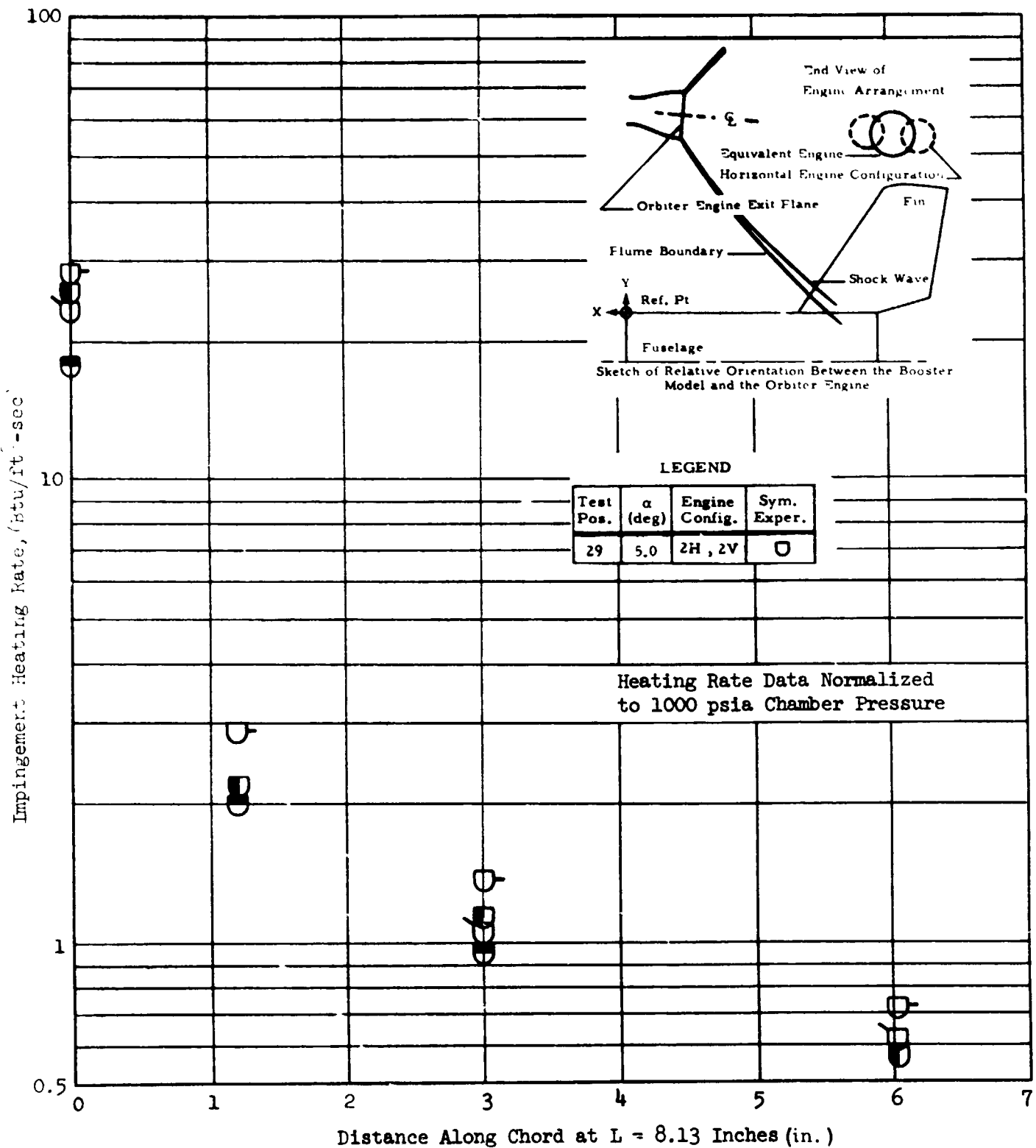


Fig. 114 - Heat Transfer Distribution Along Dorsal Fin Chord (Test Pos. 29)

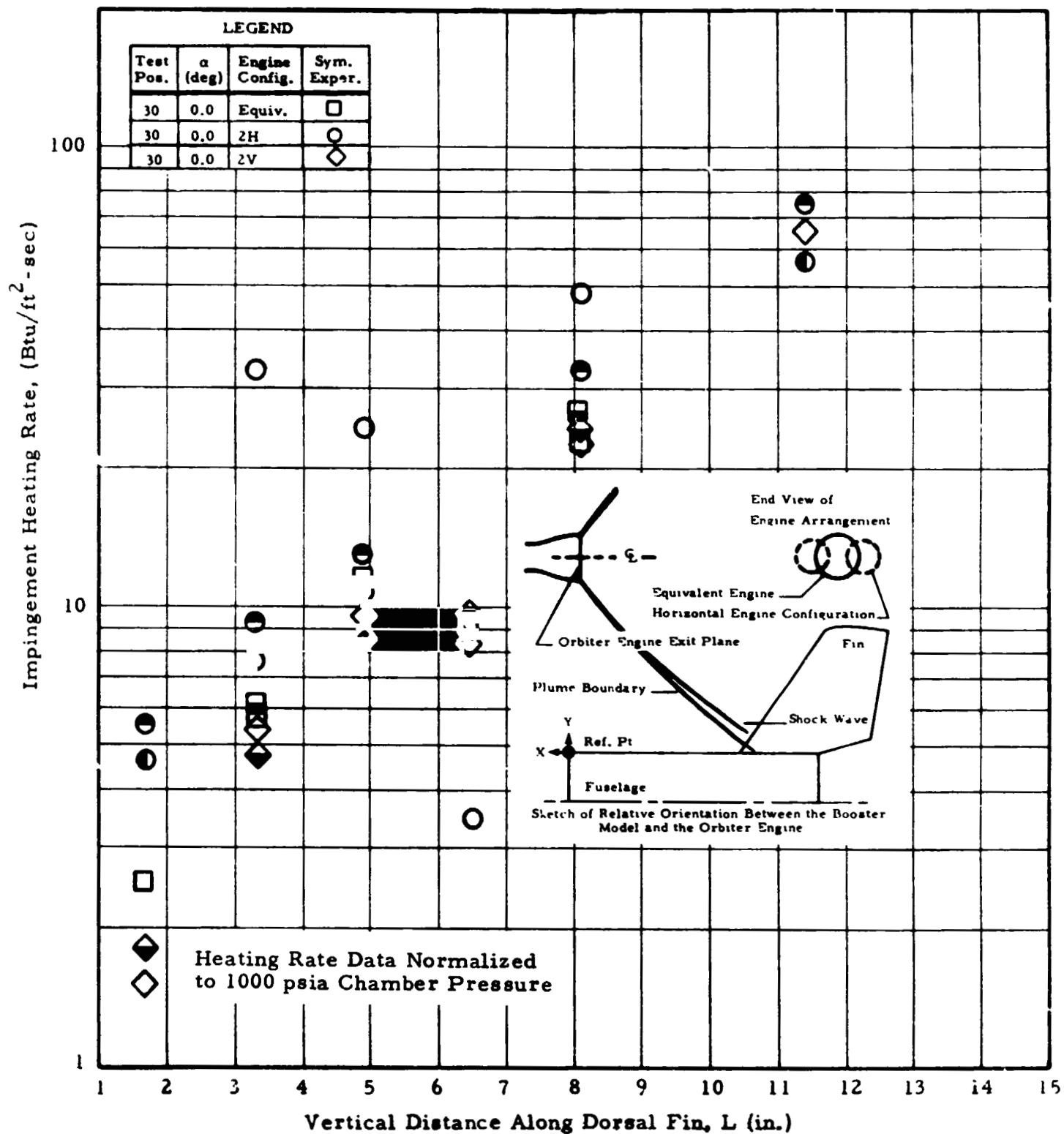


Fig. 115 - Heat Transfer Distribution Along Dorsal Fin Leading Edge (Test Pos. 30)

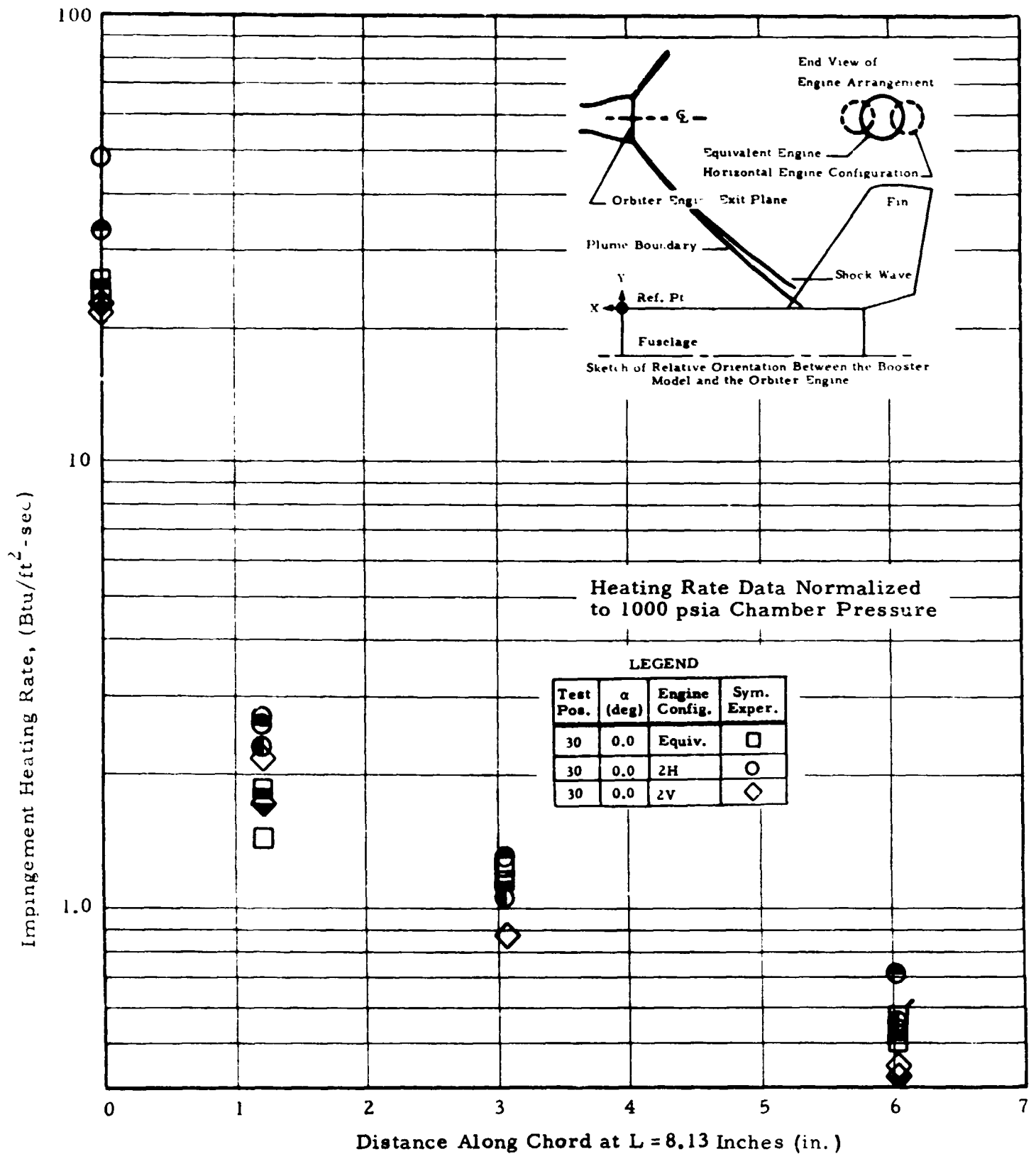


Fig. 116 - Heat Transfer Distribution Along Dorsal Fin Chord (Pos. 30)

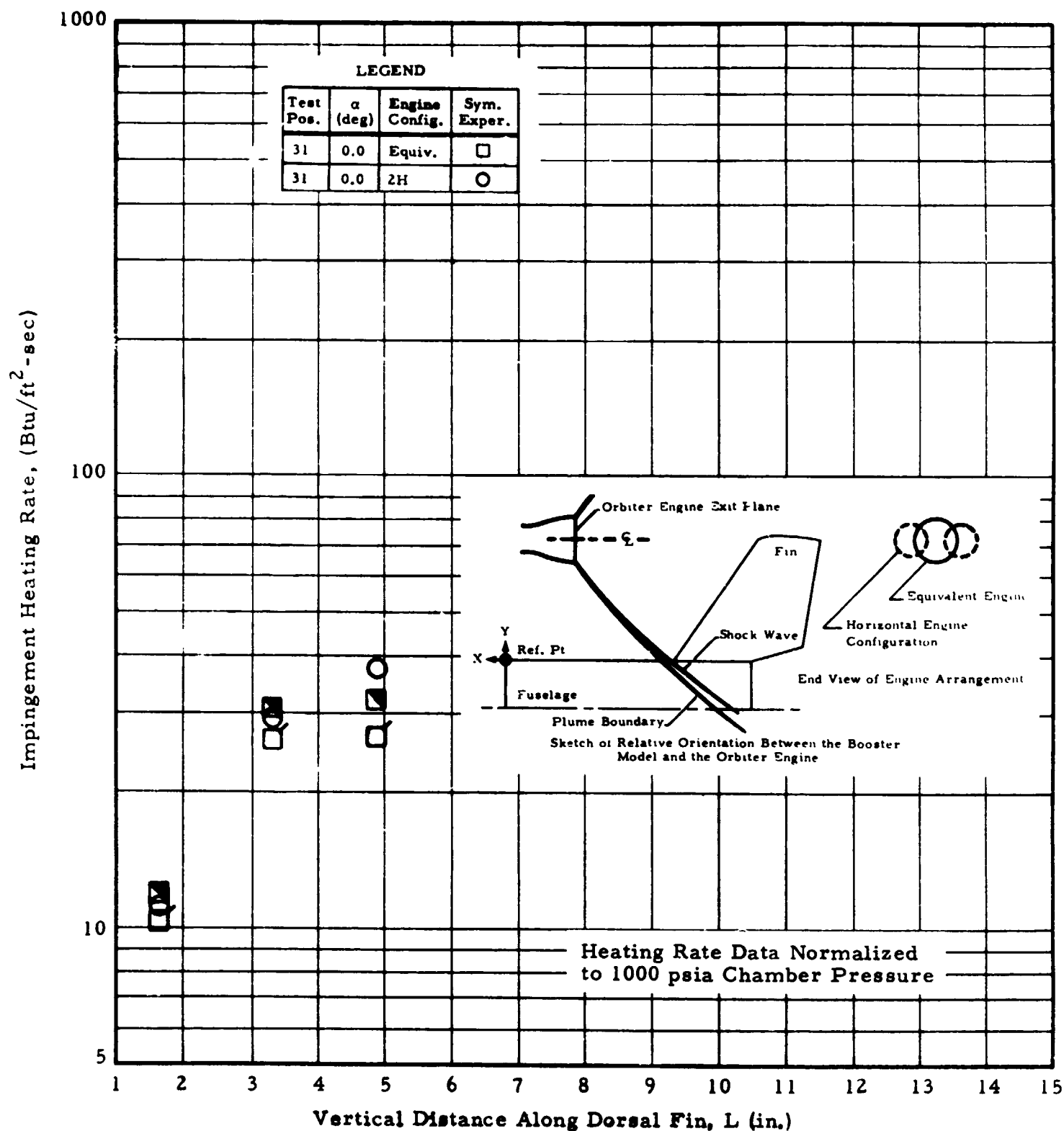


Fig. 117 - Heat Transfer Distribution Along Dorsal Fin Leading Edge (Test Pos. 31)

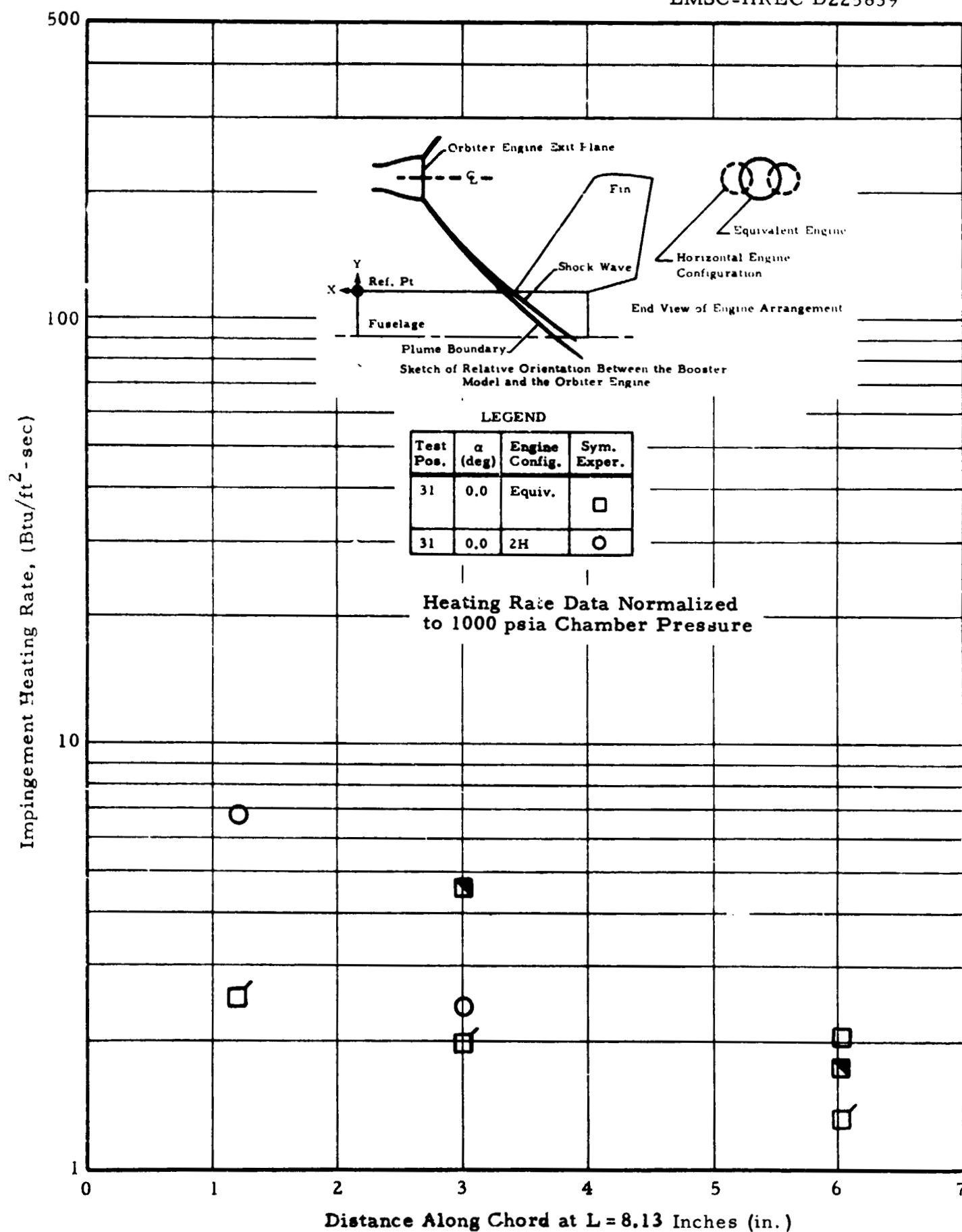


Fig. 118 - Heat Transfer Distribution Along Dorsal Fin Chord (Test Pos. 31)

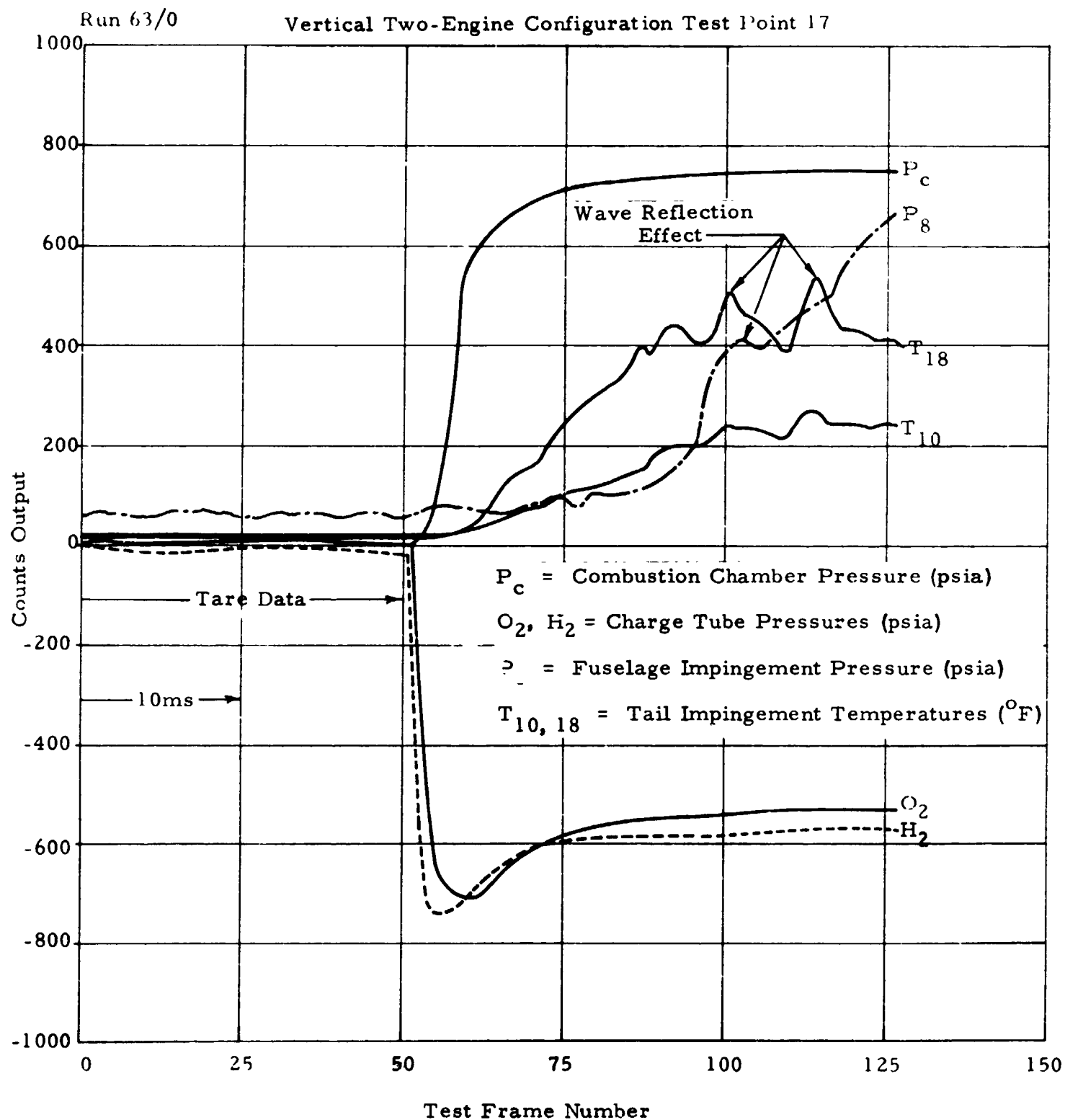


Fig. 119 - Typical Test Data Curves